



ISLS Annual Meeting 2024 June 10-14, 2024
Learning as a Cornerstone of Healing, Resilience, and
Community

**4th Annual Meeting of the International
Society of the Learning Sciences (ISLS)**

Proceedings

Edited by: Christopher Hoadley & X. Christine Wang



**International Society of
the Learning Sciences**



University at Buffalo
Graduate School of Education

ISLS Annual Meeting 2024
*Learning as a Cornerstone of Healing, Resilience, and
Community*

Buffalo, USA, June 10-14
Workshops: June 8-9
University at Buffalo

**4th Annual Meeting of the
International Society of the Learning
Sciences (ISLS)**

Proceedings

Editors:
Christopher Hoadley & X. Christine Wang



ISLS Annual Meeting 2024

Learning as a cornerstone of healing, resilience, and community

Buffalo, USA, June 10-14

Workshops: June 8-9

University at Buffalo

© 2024 International Society of the Learning Sciences, Inc. [ISLS]. Rights reserved.



www.isls.org

ISBN: 978-1-7373306-9-1 (General Proceedings, PDF Version)

ISSN: XXXXXXXX

Cite as: Christopher Hoadley, & X. Christine Wang (Eds.). (2024). *General Proceedings of the 4th Annual Meeting of the International Society of the Learning Sciences 2024*. Buffalo, USA: International Society of the Learning Sciences.

All rights reserved. Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear the copyright notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior written permission of the International Society of the Learning Sciences. The International Society of the Learning Sciences is not responsible for the use which might be made of the information contained in this book.

Conference logo design by Amber M. Winters, MBA, Assistant Dean for Marketing and Director of Communications and Events, Graduate School of Education, University at Buffalo.



Conference Organizers and Committees

Conference Co-Chairs

Christopher Hoadley, *University at Buffalo, USA*
X. Christine Wang, *University at Buffalo, USA*

Local Conference Committee

Christopher Hoadley, *University at Buffalo, USA*
X. Christine Wang, *University at Buffalo, USA*
Jennifer A. Meka, *University at Buffalo, USA*
Adrienne Decker, *University at Buffalo, USA*

Doctoral Consortium Co-Chairs:

William Penuel, *University of Colorado Boulder, USA*
Gaowei Chen, *University of Hong Kong, Hong Kong*
Anna Keune, *Technical University of Munich, Germany*
Breanne Litts, *Utah State University, USA*

Early Career Workshop Co-Chairs:

Julia Eberle, *Ruhr University Bochum, Germany*
Carol Chan, *University of Hong Kong, Hong Kong*
Clark Chinn, *Rutgers University, USA*

Mid-Career Workshop Co-Chairs:

Kris Lund, *University of Lyon, France*
Ming Ming Chiu, *The Education University of Hong Kong, Hong Kong*

Interactive Tools and Demos Co-Chairs:

Dimitra Tsvaltzis, *DFKI GmbH/Saarland University, Germany*
Alwyn Yen Lee, *National Institute of Education, Nanyang Technological University, Singapore*
Lina Markauskaite, *The University of Sydney, Australia*
Christopher Proctor, *University at Buffalo, USA*

Workshops and Tutorials Co-Chairs:

Mike Tissenbaum, *University of Illinois at Urbana-Champaign, USA*
Hiroki Oura, *Tokyo University of Science, Japan*
Annelies Raes, *KU Leuven, Belgium*
LuEttaMae Lawrence, *Utah State University, USA*

Hybrid Track Co-Chairs

D. Teo Keifert, *University of North Texas, USA*
Cynthia D'Angelo, *University of Illinois at Urbana-Champaign, USA*
Enrique (Henry) Suárez, *University of Massachusetts Amherst, USA*

Community Engagement Day Committee Co-Chairs

Wil Green, *University at Buffalo Graduate School of Education, USA*
Noemi Waight, *University at Buffalo Graduate School of Education, USA*



Social Media Communications Co-Chairs

Justice Walker, *University at El Paso, USA*

Jennifer Olsen, *University of San Diego, USA*

Naomi Thompson, *University at Buffalo, USA*

Stacy Scheuneman, *University at Buffalo, USA*

Accommodations Committee Co-Chairs

David Jackson, *University at Buffalo, USA*

Rachel Bonnette, *University at Buffalo, USA*

Joe Curnow, *University of Manitoba, Canada*

Volunteer Committee Co-Chairs

Adrienne Decker, *University at Buffalo, USA*

Sameer Honwad, *University at Buffalo, USA*

Grace (Yixin) Xing, *University at Buffalo, USA*

Finn Goehrig, *University at Buffalo, USA*

Essential Support Team

Nicole Hoover, *ISLS Conference Coordinator*

Caroline Hurley, *Event Coordinator*

Meagan O'Hara, *ISLS 2024 Webmaster*

Alicja Żenczykowska, *Conference System Architect*

Paulo Blikstein, *Conference System Chair*

Thomas Hillman, *EasyChair Guru*

Varun Bhatt, *Accommodations & Technology Support*

Copy Editors

Shiri Kashi, *University of Haifa, Israel*

Liat Rahmian, *University of Haifa, Israel*



Reviewers

Pre-Conference Workshops and Tutorials

Mike Tissenbaum, *University of Illinois at Urbana Champaign, USA*

Annelies Raes, *KU Leuven, Belgium*

Hiroki Oura, *Tokyo University of Science, Japan*

LuEttMae Lawrence, *Utah State University, USA*

Interactive Tools and Demos

Dimitra Tsovaltzi, *German Research Center for Artificial Intelligence, Germany*

Alwyn Vwen Yen Lee, *Nanyang Technological University, Singapore*

Lina Markauskaite, *The University of Sydney, Australia*

Chirag Bhuvaneshwara, *German Research Center for Artificial Intelligence, Germany*

Lara Chehayeb, *German Research Center for Artificial Intelligence, Germany*

Christopher Proctor, *University at Buffalo (SUNY), USA*

Doctoral Consortium

William Penuel, *University of Colorado Boulder, USA*

Gaowei Chen, *University of Hong Kong, Hong Kong*

Breanne Litts, *Utah State University, USA*

Anna Keune, *Technical University of Munich, Germany*

Early Career Workshop

Clark Chinn, *Rutgers University, USA*

Carol Chan, *University of Hong Kong, Hong Kong*

Julia Eberle, *Ruhr University Bochum, Germany*

Mid-Career Workshop

Kris Lund, *University of Lyon, France*

Ming Ming Chiu, *The Education University of Hong Kong, Hong Kong*



Preface

We are honored to welcome everyone to the 2024 Annual Meeting of the International Society of the Learning Sciences (ISLS), held in Buffalo, NY, from June 8-14. This marks the fourth year our society has hosted our two conferences together in a single annual meeting, with two separate but complementary programs: The International Conference of the Learning Sciences (ICLS) and Computer Supported Collaborative Learning (CSCL). This year, we are thrilled to gather in person again as academic travel routines have largely returned to normal post-pandemic. This annual meeting coincides with the founding of the University at Buffalo Institute for Learning Sciences.

The theme of the ISLS Annual Meeting 2024 is “Learning as a Cornerstone of Healing, Resilience, and Community.” This theme acknowledges the ongoing need to respond to global crises, including COVID-19, racism, bigotry, war, climate change, and political oppression. These challenges affect not only current events but also the lives of learners and the demands placed on educational systems. Our learning sciences community of scholars and practitioners has been touched by these crises, and we recognize the need for healing, resilience, and community in our own learning and that of our extended academic networks. We believe this theme has resonated with the ISLS community and we are pleased to report that this year's meeting has attracted an unprecedented number of attendees, with nearly 1000 registered participants, the largest ever in ISLS history. Due to space and capacity limitations, we had to close registration. This remarkable turnout highlights the society's growth and scholars' strong desire for connections.

We introduced two major innovative elements this year. First, a Community Engagement Day provides an opportunity to experientially examine how our field intersects with different forms of learning in the community through structured interactions with learning providers in Buffalo and beyond. Community Day is essential even for those who do not conduct place-based research, as it offers a broader understanding of how learning sciences can impact and be enriched by community engagement. By stepping outside traditional academic settings, attendees can gain fresh perspectives and new ideas that can inform and enhance their own research and practice. Second, we introduced a new hybrid format: “born hybrid” symposiums outlining their aims and strategies for hybrid engagement. These sessions were reviewed for both content and format, prioritizing those that clearly demonstrate the added value of online hybridity. While we recognize that technology is transforming how conferences are conducted, and many people depend on virtual or hybrid formats to participate in professional events, this strategy is an experimental step toward future hybrid engagement.

This year, we present five keynote speakers, including three learning scientists and two complementary experts. Dr. A. Susan Jurow from the University of Colorado, Boulder, USA, explores the design potential for healing in her talk, “Can we design for healing in the Learning Sciences?” Dr. Wenli Chen from Nanyang Technological University (NTU), Singapore, discusses “Techno-Pedagogical Design to Prepare Future-Ready Collaborative Learners in Authentic Classroom Settings.” Dr. Nichole Pinkard from Northwestern University, USA, presents “Opportunity Landscaping: A Framework for Community-led Transformation of Hyperlocal Learning Ecosystems.” Additionally, for our Community Day, we have two keynote speakers. Jillian Hanesworth, Buffalo’s first Poet Laureate, who provokes the community with her talk “When ‘Why’ Comes Before ‘What.’” Dr. Jason Corwin from the University at Buffalo, USA and founder of the Seneca Nation Media and Communications Center discusses the importance of grounding educational experiences in place and community in his presentation, “Land-based Learning: Grounding Experiences in Place and Community.”

In addition to the keynote presentations, this General Proceedings includes the cross-cutting, joint events of the ISLS Annual Meeting: Invited Sessions, Pre-Conference Workshops & Tutorials, Mentoring Workshops (Doctoral Consortium, Early Career Workshop, Mid Career Workshop), and Interactive Tools & Demos. The organization of this Annual Meeting has been supported by several standing committees of ISLS, with particular appreciation for the continuous support from the Annual Meeting Committee, the Communications Committee, and the Membership Committee. We gratefully acknowledge a U.S. National Science Foundation (NSF) Grant sponsoring the Doctoral Consortium and workshop-related activities/events under grant DRL-2428717 (Any opinions, findings, and conclusions



or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.) We also extend our gratitude for the significant financial and in-kind support from the University at Buffalo's Graduate School of Education. Our society, ISLS, has made significant efforts to support the participation of community members with specific needs, including tiered registration pricing and substantial financial assistance through the Equity Assistance Committee of ISLS. Additionally, the local organizers introduced a comprehensive accommodations policy, which for the first time systematically ensures that reasonable accommodations are available not only for disabilities but also for other hardships such as visa status or caretaking responsibilities.

Finally, we extend our deepest gratitude to everyone, especially volunteers, who dedicate their time to all aspects of this meeting, reviewing papers, and participating in the event. Together, we have created an enriching, productive, and vibrant community event. We hope this annual meeting serves as an invitation to strengthen our practices leading to human flourishing.

Christopher Hoadley and X. Christine Wang
Conference Co-Chairs
June, 3, 2024 in Buffalo



Acknowledgments

ISLS Annual Meeting 2024 conference organizers would like to give special thanks to the following committees and people for their support:

- International Society of the Learning Sciences (ISLS)
- ISLS Board of Directors and Executive Committee
- University at Buffalo, USA
- Wallace Foundation
- National Science Foundation (NSF)
- EasyChair Support Team
- Whova Support Team
- Conference Organizing Committee including
 - LS and CSCL Program Committees
 - Hybrid Track Co-chairs
 - Community Engagement Day Committee Co-Chairs
 - Social Media Communications Co-Chairs
 - Accommodations Committee Co-Chairs
 - Volunteer Committee Co-Chairs
 - Doctoral Consortium Co-Chairs
 - Early Career Workshop Co-Chairs
 - Mid-Career Workshop Co-Chairs
 - Interactive Tools and Demos Co-Chairs
 - Pre-Conference Workshops and Tutorials Co-Chairs
 - ISLS 2024 Essential Support Team
- Reviewers and Sr. Reviewers
- Best Paper Award Committees
- Conference Proceeding Copy Editors



Table of Contents

ISLS Proceedings

Keynotes

Can We Design for Healing in the Learning Sciences?	3
<i>A. Susan Jurow</i>	
Techno-Pedagogical Design to Prepare Future-Ready Collaborative Learners in Authentic Classroom Settings	4
<i>Wenli Chen</i>	
Opportunity Landscaping: A Framework for Community-led Transformation of Hyperlocal Learning Ecosystems	5
<i>Nichole Pinkard</i>	
When “Why” comes before “What”	6
<i>Jillian Hanesworth</i>	
Land-based Learning: Grounding Experiences in Place and Community	7
<i>Jason Corwin</i>	

Interactive Tools and Demos

Integrating Math and Science through Interactive Simulations	10
<i>Nicole Panorkou, Amanda Provost</i>	
Viacocrea: A Cocreative Support Technology	12
<i>Manoli Pifarré</i>	
Orchestration Assistant: A Real-time Teacher Guidance Tool	14
<i>Daeun Hong, Chen Feng, Kelli Paul, Xiaotian Zou, Cindy E. Hmelo-Silver, Seung Lee, Tianshu Wang, Kimberly Farnsworth, Krista Glazewski, Bradford Mott, James Lester</i>	
TRFlens: A Visual Learning Analytical Tool to Support Teacher Video-Based Reflection and Feedback on Classroom Dialogue	18
<i>Chao Yang, Gaowei Chen</i>	
DEMO: A Tabletop Action-Based Embodied Design for the Cartesian System	21
<i>Ilona Ilowiecka-Tańska, Katarzyna Potega vel Źabik, Dor Abrahamson</i>	
Enhancing Pre-service Teachers’ Competence with a Generative Artificial Intelligence-Enhanced Virtual Reality Simulation	24
<i>Juno Hwang, Sumin Hong, Taeyeon Eom, Cheolil Lim</i>	
We’re in This Together (WIT): Leveraging Mixed Reality to Explore Complex Systems	28
<i>Dan Roy, Sharleen Loh, Daniel Wendell, Aditi Wagh</i>	
Tangible ScratchJr	30
<i>Jessica Blake-West, Marina Bers</i>	
Learning Along Digital Lines: Using Structure from Motion to Analyze Place-Based Trajectories in Virtual Reality	33
<i>Erin Riesland, Katie Headrick Taylor</i>	
Cultivating Resilience: A Participatory Approach to STEAM Curriculum in Community Gardens	36
<i>Benedetta Piantella, Syeda Anjum</i>	
BurnAR, ARScope, and Magic Arrow: Improving Interactive and Pedagogical Design in Augmented Reality-based Learning	38
<i>Parastoo Alikhani, Pooya Sabeti</i>	
The Synthesis Lab: Facilitating Sustained Knowledge Creation in Collaborative Discourse	41
<i>Xinran Zhu, Hong Shui, Ishan Joshi, Wenxi Chen, Bodong Chen</i>	



LS Explorer: An AI Tool for Navigating Learning Sciences Research using Retrieval-Augmented Generation (RAG).....	45
<i>Yipu Zheng, Paulo Blikstein</i>	
“The Isles of Ilkmaar”: A Data-rich, Multiplayer Virtual World for Teaching Data Science to Middle School Learners.....	49
<i>Lisa Hardy, Sarah Radke, Jennifer Kahn</i>	
Math of Facial Recognition: Co-Design of a Machine Learning and Statistics iItegrated Curriculum for High School	53
<i>Victoria Delaney, David Dobervich, Isabel Sieh, Megan Selbach-Allen</i>	
Pre-Conference Workshops	
Bite-Sized Assessments: Creating Micro-credentials for Buffalo Chicken Wings.....	59
<i>Samuel Abramovich, Peter Wardrip</i>	
A Gathering to Synthesize, Critically Examine, and Envision New Horizons for Learning Sciences Research on “Failure” and Learning	63
<i>David DeLiema, Maleka Donaldson, Luis Morales-Navarro, Colin Hennessy Elliott, Amber Simpson</i>	
Cultivating Ensembles at ISLS.....	67
<i>Marisa A. Holzapfel, Carolyn D. Sealfon, Barbara J. Natalizio, Raquell M. Holmes</i>	
A.I. Augmented Learning for All: Challenges and Opportunities, A View from the Five National AI Institutes	69
<i>Jinjun Xiong, James Lester, Jonathan Rowe, H. Chad Lane, Jeremy Roschelle, Ashok Goel, Peter Foltz</i>	
Network of Academic Programs in the Learning Sciences: Reigniting NAPLeS	73
<i>Marcela Borge, Daniel Hickey, Freydis Vogel</i>	
Educating for Ecological Caring on a Damaged Planet: Designing and Building Refugia with/for More-than-humans	76
<i>Kelsie Fowler, Marijke Hecht, Philip Bell, Anastasia Sanchez, Kaleb Germinaro, Chris Jadallah, Nancy Price</i>	
Learning {Blank} Science Fiction and Fantasy: Exploring the Relationship between Gnre F\ction and the Learning Sciences.....	80
<i>Deborah Dutta, Suraj Uttamchandani</i>	
Maximizing the ISLS 2024 Annual Experience: A Community-Based Workshop for Polishing Presentation and Conferencing Skills.....	84
<i>Sarah Bichler, Katharina M. Bach</i>	
Towards a Transformative Action Research Network.....	88
<i>Sameer Honwad, Preeti Raman, James D. Slotta, Paulo Blikstein, Akshay Kedari, Christopher Hoadley, Yeshi Paljor, Shakuntala Gopal, Devayani Tirthali, Abhijit Kapre, Renato Carvalho</i>	
Exploring the Content and Structure of a Framework for Learning Progressions for K-12 Data Science Education.....	92
<i>Katherine M. Miller, Chad Dorsey, Zarek Drozda</i>	
Healing Justice in Youth Organizations and Schools: Research Methods and Ethical Provocations	96
<i>Ben Kirshner, Beatriz Salazar, Lex Hunter, Solicitud Lopez, Jessica Fernández, Rashida Govan, Elizabeth Mendoza</i>	
Designing for Learning and Healing in the Aacademy.....	99
<i>Krista Cortes, A. Susan Jurow, Elizabeth Mendoza</i>	
The Hidden Majority: Examining the Inaccessibility Crisis as a Barrier to Equitable Education	102
<i>C. Naomie Williams, Margaret Ellen Seehorn, Mia Ellis-Einhorn, Haiyi Zhu Carnegie Mellon University, Vincent Aleven</i>	



Knowledge Building and Generative AI to Advance Community Knowledge 106

Lydia Cao, Marlene Scardamalia, Carl Bereiter, Stacy Costa, Monica Resendes, Dina Soliman, Ahmad Khanlari, Boris Steipe, Jianwei Zhang, Mei-Hwa Che, Bodong Chen, Thérèse Laferrière, Yuqin Yang, Carol K.K. Chan, Gaoxia Zhu, Chew Lee Teo, Fernando Castillo, Preeti Raman, Linda Massey

Designing for Powerful Ideas in Educational Robotics in the Era of AI 110

Walter Akio Goya, Jonathan Pang, Paulo Blikstein, Leah F. Rosenbaum, Arnan Sipitakiat, Peeranut Pongpakati

Reimagining and Advancing CSCL Research and Building CSCL Community 114

Carol K. K. Chan, Michelle Lui, Jun Oshima, Bodong Chen, Annelies Raes, Wenli Chen, Omid Noroozi

Early Career Workshops

Integrated STEM Education: Empowering Students' Epistemic Agency through Ambitious Instruction 120
Jooeun Shim

A Two-Pronged Approach for Improving Mathematics Education at Scale: Researching Teacher Learning and Organizational Change 122

Phi Nguyen

Deliberate, Guided Failure 124

Tanmay Sinha

Taking a Relational Approach to Study Learning: Science Education in and with the More Than Human World 126

Rishi Krishnamoorthy

Using Multimodal Collaboration Analytics to Support Collaborative Problem Solving 128

Rogers Kaliisa

Determining the Effectiveness of Authentic Learning 130

Valentina Nachtigall

Empowering Learners through Technologies and Preparing them for a Data-driven World 132

Rotem Israel-Fishelson

Understanding Student Engagement Through a Sociocultural Lens in Technology-Mediated Learning Environments 134

Megan Humburg

Bridging Boundaries: Interdisciplinary Learning, Educational Technologies, and Future Workforce Preparation 136

Joey Huang

Towards Equitable STEM Participation: Fostering Critical Collaborative Competence in Meaningful Collaborative Processes 138

Tugce Aldemir

Doctoral Consortium

Developing the Design Principles of Thinking Routines-Embedded Instruction: A Design-Based Research ... 142
Jou-Yin Chen

Understanding Mongolian Nomadic Herders' Learning During Participation in an Adaptation Intervention ... 144
Qiuyan Wu

“We can be researchers too”: Exploring Teacher Agency Changes in Research-Practice Partnerships 146
Shuqin Li

Narratives in Augmented Reality Game-based Learning 148
Kevin Palzer

Interdisciplinary Dialogic Argumentation and Change in Epistemic Practices among Science Teachers 150
David Perl-Nussbaum



Understanding Longitudinal Teacher Learning across Co-Design and Enactment of Curricular Materials.....	152
<i>Katarzyna Pomian Bogdanov</i>	
Designing Multimodal Expert Feedback in Team-based Simulations.....	154
<i>Daniel Sánchez</i>	
Tree Climbing: Attunement to Material Contribution during Playful Climbing	156
<i>Megan Goeke</i>	
Threads of Dreaming: Cultivating Relations as a Commitment to What Could (And Should) Be in Queer and Trans Communal Clothing Making	158
<i>Ali R. Blake</i>	
“To Live in the Along”: Refugee Youth Organizing and Intergenerational Learning.....	160
<i>Sarah Priscilla Lee</i>	
Imagination and Action in Mathematical Reasoning and Transfer	162
<i>Fangli Xia, Mitchell J. Nathan</i>	
Materials-To-Queer-With: Weaving a Queering of Undergraduate Mathematics.....	164
<i>Nickolina Yankova</i>	
Exploring Motivational Beliefs in Middle School Makerspaces: Analysis of Socio-cognitive Influences, Material Interactions, and Gender Dynamics	166
<i>Nisumba Soodhani K</i>	
Enhancing Teacher Reflection and Feedback on Classroom Discourse During Video-Based Professional Development: A Visualization Approach.....	168
<i>Chao Yang, Gaowei Chen</i>	

Keynotes



International Society of
the Learning Sciences



Can We Design for Healing in the Learning Sciences?

A. Susan Jurow, University of Colorado, Boulder, susan.jurow@colorado.edu

Abstract: Learning is, as the conference theme names, a cornerstone for healing. What do we mean by healing and if this is something we desire, can we design for it? My answer is a tentative yes. “Tentative” because we must be careful not to use healing as a buzzword or treat it like a panacea. As responsible learning scientists, we need to recognize and study the histories and diverse roots of healing traditions and consider how they might carefully ground our designs.

In this talk, I share my journey to understanding the need for individual and institutional healing. My approach to healing is guided by what I call principles of CARE – Communal action, engagement with the creative Arts, Reimagining methodology and evidence, and Embodying care in our research and pedagogy. Using these principles, I will use examples from my and others’ work to draw attention to how designs for healing can support social change alongside the development of new forms of learning and unlearning.

Bio: Dr. A. Susan Jurow is Professor of Learning Sciences & Human Development at the University of Colorado, Boulder. She is also Co-Editor-in-Chief of *Journal of the Learning Sciences* (2021-2024). Dr. Jurow’s scholarship centers on ameliorating systems that marginalize communities. Her work involves research and design with historically non-dominant youth in school and community settings, progressive social activists, and technology designers. Across these contexts, Dr. Jurow and her collaborators foreground people’s capacity to organize new futures while struggling against systems of oppression. Dr. Jurow is also co-founder of the Healing, Empowerment, And Love (HEAL) program aimed at addressing academic harm for women of color graduate students through racial healing and holding space to deepen participants’ connection to their inner wisdom.



Techno-Pedagogical Design to Prepare Future-Ready Collaborative Learners in Authentic Classroom Settings

Wenli Chen, Nanyang Technological University (NTU), wenli.chen@nie.edu.sg

Abstract: Fostering collaborative learning among school students is more crucial than ever in today's interconnected yet conflict ridden world. As we prepare the students to tackle the complex challenges, it is imperative to design and sustain meaningful computer-supported collaborative learning (CSCL) environments within authentic classrooms. Drawing her extensive experiences in design-based research involving over 600 students cross 7 Singapore schools, Wenli CHEN will share her insights on working with school teachers to integrate CSCL theories, pedagogical know-how and educational technologies to design and implement computer-supported collaborative argumentation to foster problem solving, critical, adaptive and inventive thinking, conflict resolution and empathy among learners. Wenli's research focuses on strengthening the nexus between CSCL research and its practical implementation in authentic classrooms. In this talk, she will discuss the technological and pedagogical scaffolds, particularly the Spiral Model of Collaborative Knowledge Improvement, that facilitate both small group and larger class collaborative learning within a limited curriculum time frame. In addition to the applied translation of learning sciences and CSCL theories to classroom practices, Wenli has tested her learning designs in lab settings using a multi-modal learning analytics approach to better understand how and when CSCL works. The talk covers these learning analytics-informed design principles that contribute to effective collaborative learning experiences.

Bio: Wenli CHEN is an Associate Professor and Head of the Learning Sciences and Assessment Academic Group at the National Institute of Education, Nanyang Technological University (NTU) Singapore. Her specialization lies in Computer-Supported Collaborative Learning (CSCL) and learning analytics. Her research has been recognized with the "Distinguished Researcher Award" from the Asia-Pacific Society for Computers in Education and the Nanyang Education Award from NTU. Presently, Wenli serves as the Editor-in-Chief for both the Journal of Computers in Education, and Learning: Research and Practice. She also serves as an Associate Editor for Instructional Science, Asia Pacific Journal of Education, and Research and Practice in Technology Enhanced Learning. Moreover, she is an editorial board member for the International Journal of Computer-Supported Collaborative Learning. She is the executive committee member of the Asia Pacific Society of Computers in Education and the Global Chinese Society of Computers in Education. She also served as co-chair of the CSCL Community Committee of the International Society of the Learning Sciences from 2016 to 2021. She was the Program Committee Co-chair for the International Conference of CSCL in 2022, and the Co-chair for International Conference of the Learning Sciences 2016. She chaired the Program Committee for the International Conference on Computers in Education 2017, and the Global Chinese Conference on Computers in Education 2014.



Opportunity Landscaping: A Framework for Community-led Transformation of Hyperlocal Learning Ecosystems

Nichole Pinkard, Northwestern University, nichole.pinkard@northwestern.edu

Abstract: This keynote introduces “Opportunity Landscaping,” a framework aimed at redefining the utilization of local educational landscapes to foster equitable learning opportunities across a community’s geography. The keynote will examine how two research-community practice partnerships have leveraged this framework to develop opportunity landscapes- a comprehensive aggregation of learning and leisure resources localized within specific geographical boundaries- to understand the historical impact of policies such as redlining and school desegregation on equitable access to their community’s hyperlocal learning opportunities. Finally, the keynote will challenge the field to collaboratively develop the socio-technical systems necessary to engage in cross-community collaborations to develop shared practices for increasing equitable access to joyful learning opportunities in historically under-resourced geographies.

Bio: Nichole Pinkard, Alice Hamilton Professor of Learning Sciences at Northwestern University, is the founder of Digital Youth Network and L3, a social learning platform that connects youth’s learning opportunities across the school, home, community, and beyond. Through collaborations with city agencies Pinkard and DYN’s work has ignited new models for reimagining, visualizing, and documenting learning across spaces through the creation of existence proofs in urban contexts.

Pinkard received a 2010 Common Sense Media Award for Outstanding Commitment to Creativity and Youth, the Jan Hawkins Award for Early Career Contributions to Humanistic Research and Scholarship in Learning Technologies, an NSF Early CAREER Fellowship. She earned her bachelor’s in computer science from Stanford University, a master’s in computer science from Northwestern, and her doctorate in learning sciences from Northwestern’s School of Education and Social Policy. Her current scholarly interests include the design and use of pedagogical-based social networks and socio-technical systems to support community-level ecological models of learning.



When “Why” comes before “What”

Jillian Hanesworth, Buffalo’s First Poet Laureate, hanesworth.jc@gmail.com

Abstract: We all want to change the world or at least impact it somehow. Some of us do so through institutions of education, activism, arts, etc. We decide what we want to be and paint a vision in our minds that fuses together what we want to accomplish and how it can leave a lasting impression on society. Imagine if we put our “why” first. This poetic lecture will place an emphasis on the importance of know why we do what we do and the benefits of putting our “why” first.

Bio: Jillian Hanesworth is an Emmy Award winning spoken word artist, the Poet Laureate Emeritus of Buffalo, New York and a community organizer and activist. Jillian was born and raised on the east side of Buffalo where she developed a vision to use art and advocacy to help her community reimagine justice and work together to create a system where all people can thrive.

Currently, Jillian travels the country performing poetry and speaking on various topics including; art for activism, the impacts of storytelling and the importance of honest and critical social and political conversations. In addition, Jillian oversees “Buffalo Books”, a nationally recognized program which aims to improve access to culturally relevant books for residents of the east side of Buffalo with the hopes of helping to increase literacy rates among Black and brown communities.



Land-based Learning: Grounding Experiences in Place and Community

Jason Corwin, University at Buffalo, jcorwin@buffalo.edu

Abstract: For the past two years at the University at Buffalo, Indigenous and non-Indigenous students alike have found land-based learning to be a highly engaging, informative, and rewarding educational experience. Through hands-on experiential learning activities during field trips to the Letchworth Teaching Woods on campus, local sites of significant history, and nearby Indigenous territories (reservations), students learn directly from Indigenous community members about Haudenosaunee environmental philosophy and knowledge, while strengthening their relationships with the natural world and each other. These courses are the latest offerings from an educator whose 18 year pedagogical practice has merged land-based learning with digital storytelling and civic engagement on environmental, social, and ecological justice issues.

Bio: Dr. Jason Corwin is a citizen of the Seneca Nation, Deer Clan and a lifelong media maker. He was the founding director of the Seneca Media & Communications Center and has produced several short and feature length documentaries. Dr. Corwin has extensive experience as a community-based environmental educator utilizing digital media to engage with Indigenous ways of knowing, sustainability, and social/environmental justice topics. His research is situated at the confluence of Indigenous ways of knowing, environmental education, and digital media. It highlights Native peoples' and communities' work to achieve narrative sovereignty, sustainability, and environmental justice.

Interactive Tools and Demos



International Society of
the Learning Sciences



Integrating Math and Science through Interactive Simulations

Nicole Panorkou, Montclair State University, panorkoun@montclair.edu
Amanda Provost, Montclair State University, provostal@montclair.edu

Abstract: We present a selection of simulations and accompanied tasks designed to integrate math and scientific reasoning within the context of real-world science phenomena.

Background

There have been several calls to make mathematics more transparent and explicit in STEM learning (e.g., Shaughnessy, 2013). Therefore, our research group aimed to design instructional modules that illustrate the *reciprocal relationship* (Fitzallen, 2015) between math and STEM. This included designing activities in which STEM learning not only provides context but also support for math learning, while math concepts and practices are used in such a way to support learning in other STEM fields. For our design, we also explored the potential of using digital environments that dynamically model abstract mathematical and scientific concepts. When looking at the use of technology for supporting this integrated learning, we found that existing digital simulations and virtual manipulatives target either math or science learning, not allowing for a productive interaction of both disciplines that would promote their reciprocal relationship. To address this gap in design, we developed a set of interactive digital simulations that can be used to integrate math and science learning in the middle grades.

In this design process, our group of mathematics educators collaborated and negotiated with a group of environmental scientists. To elaborate, scientific phenomena include complex relationships that are often not accessible to middle schoolers. However, by compromising a specific degree of scientific accuracy we were able to maintain the scientific integrity of the model while creating an accessible data set for middle school students to investigate. In other words, we considered our simulations to be simplified models of real-world processes designed to have useful pedagogical features (Weintrop et al., 2016).

Our design aimed to provide students with opportunities for inquiry practices such as questioning, hypothesis development, data collection, and theory revision (Rutten et al., 2012). This utilization of simulations aligns with Weintrop et al.'s (2016) computational practices of collecting, analyzing, and visualizing data. Specifically, we paid meticulous attention to task and question design, intending to redirect students' focus to specific elements of the model and influence their interactions with those elements. This questioning structure aimed to prompt students to explore relationships, fostering mental actions associated with particular math and science forms of reasoning, such as covariational and multivariable reasoning (Panorkou & Germia, 2023; Thompson & Carlson, 2017) and systems thinking (Kali, 2018). To support students' math and scientific learning, our task design prompted transitions between multiple artifacts, such as tables and graphs (Panorkou et al., 2023).

Simulations and demo

We designed a total of 10 instructional modules and 19 simulations. In our demo session, we will provide a brief introduction to our project and the principles that guided our designs. We will then engage the audience in a guided hands-on exploration of some of our simulations and tasks. We will then solicit feedback and questions relating to the simulations and their applications. Below we provide four examples of our simulations.

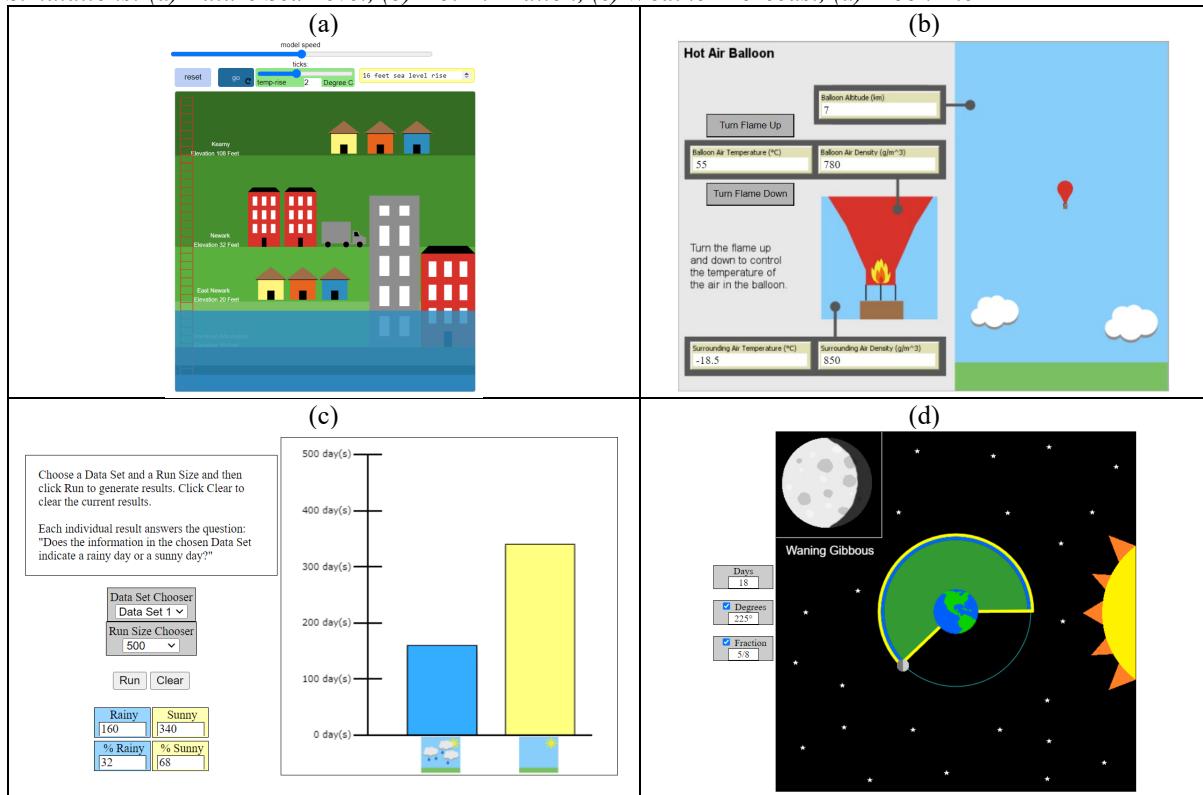
The Future Sea Level simulation (Figure 1a) was designed as part of our Greenhouse Effect module. Students can change the amount of temperature rise and observe the change in sea level rise as well as the total land area remaining. The simulation aims to bring issues of climate and social justice to the math classroom (Basu & Panorkou, 2020) by having students explore four cities in New Jersey at different elevations.

For our Weather module, we designed the Hot Air Balloon simulation (Figure 1b) that allows students to manipulate the flame of a hot air balloon and observe how the temperature and air density change both inside and outside the balloon as its altitude changes. In this module, we also designed the Weather Forecast (Figure 1c) simulation to help students explore how probability is used in making weather forecast predictions. It demonstrates the Law of Large Numbers by allowing students to generate samples ranging in sample size from 1 to 100,000 from different data sets. Students were asked to create a table and graph of the run size versus the chance of rain on a logarithmic scale and notice how the percentage of rainy days approached a value.

The Moon Pie simulation (Figure 1d) in the Lunar Phases module was designed to explore how the position of the moon in its orbit leads to our perception of the lunar phases. Students can drag the moon in its simplified 28-day orbit around earth and can toggle on and off fraction and angle measures and wedge overlays. Students can observe the covariational relationship between the fraction and angle measures and use proportional reasoning to identify patterns related to the position of the named lunar phases (Provost & Panorkou, *in press*).

Figure 1

Simulations: (a) Future Sea Level, (b) Hot Air Balloon, (c) Weather Forecast, (d) Moon Pie



References

Basu, D., & Panorkou, N. (2020). Utilizing mathematics to examine sea level rise as an environmental and a social issue. In A. I. Sacristán, J. C. Cortés-Zavala, & P. M. Ruiz-Arias (Eds.), *Proceedings of the 42nd Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 1064-1068).

Fitzallen, N. (2015). STEM education: What does mathematics have to offer? *Mathematics Education Research Group of Australasia*, Sunshine Coast, Queensland, Australia.

Kali, Y. (2018). A virtual journey within the rock-cycle: A software kit for the development of systems-thinking in the context of the Earth's crust. *Journal of Geoscience Education*, 51(2), 165-170.

Panorkou, N. & Germia, E. (2023). Young students' forms of reasoning about multiple quantities. *For the Learning of Mathematics*, 43(1), 19-23.

Panorkou, N., York, T., & Germia, E. (2023). Examining the "messiness" of transitions between related artifacts. *Digital Experiences in Mathematics Education* 9, 131–162.

Provost, A., & Panorkou, N. (in press). Exploring lunar phases with the moon pie simulation. *Mathematics Teacher: Learning and Teaching PK-12*.

Rutten, N., Van Joolingen, W. R., & Van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education*, 58(1), 136-153.

Shaughnessy, J. M. (2013). Mathematics in a STEM context. *Mathematics Teaching in the Middle School*, 18(6).

Thompson, P. W., & Carlson, M. P. (2017). Variation, covariation, and functions: Foundational ways of thinking mathematically. In J. Cai (Ed.), *Compendium for research in mathematics education* (pp. 421-456).

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology*, 25(1), 127-147.

Acknowledgments

This research was supported by the National Science Foundation (#1742125). We thank our all the members of the ACMES project team for their support in the design, creation, and implementation of these simulations.



Viacocrea: A Cocreative Support Technology

Manoli Pifarre, Universitat de Lleida, Spain, manoli.pifarre@udl.cat

Abstract: Cocreation is an essential competence to generate novel solutions for complex challenges faced in organizations. It has been highlighted the positive role that technologies can play in engaging people in cocreative settings. However, little is explored about how technology can support all the stages of a cocreative process capable to generate and implement innovative solutions to a complex challenge in real classrooms. To tackle this challenge, Viacocrea has been designed and implemented. Viacocrea provides to teachers and students with a multi-user, collaborative and synchronic cocreative space to generate and solve complex challenges. Viacocrea structures the whole cocreative process in six phases; enriches the cocreative process with ready to use techniques and resources the cocreation space with video-tutorials and infographics. Viacocrea is aligned with the 21st century curriculum and it can be easily integrated in secondary classrooms, vocational training, and higher education to develop students' cocreative mindset.

Introduction

The acknowledgment of creativity as a crucial 21st-century skill is now ingrained within educational policies and curricula, recognizing its pivotal role in both professional pursuits and personal growth. Educational research claims that creativity is a complex and multifaceted concept that emerges in social and situational contexts, requiring iterative and improvisational creative processes, particularly in collaborative settings (Sawyer, 2022). Within modern classrooms, Project-Based Learning (PBL) methodology stands out as a vehicle for nurturing co-creativity, presenting students with authentic, open-ended challenges. It also promotes collaborative learning by incorporating technology to enhance and enrich the teaching and learning experience. Furthermore, PBL methodology encapsulates the four pedagogical facets outlined by Sawyer (2022) as essential for cultivating creativity: a) iterative (non-linear); b) ambiguity; c) exploration; and d) emergence (where ideas materialize through hands-on engagement). Nonetheless, educators often encounter challenges in integrating innovative teaching methodologies and explicitly instilling creativity within daily classroom activities. The importance of collaboration or teamwork to solve complex problems and generate innovative solutions indicates that groups often perform sub-optimally (e.g., Sawyer, 2021). This is because groups need to orchestrate multi-dimensional variables (such as behavioral, emotional, and cognitive variables) distributed at multiple levels (such as individual, peer, and group levels) and developed over time (Ouyang et al., 2023).

In recent years, advancements in interactive technologies have shed light on their potential to foster engagement, develop high-level cognitive and social processes involved in cocreation (Sun et al., 2022), help both students and teachers in learning and teaching processes (Richardson, 2022). Yet, little is explored about how technology can support all the stages of a cocreative process capable to generate and implement innovative solutions to a complex challenge in real-classroom context. To address this gap, within the framework of two research projects funded by the Spanish Research Agency, we have designed and implemented the Viacocrea Technology. This innovative platform provides to teachers and students an interactive, supportive, resourceful, and multiuser space for developing cocreative processes and mindsets.

Viacocrea technology

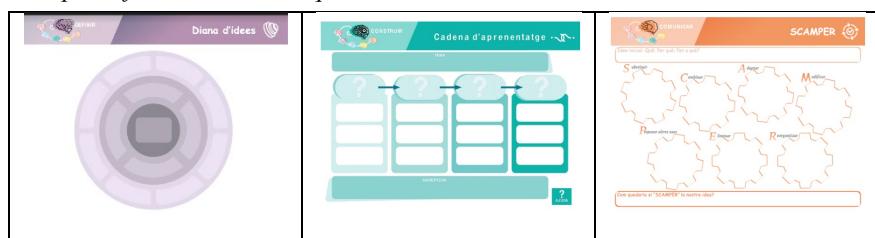
Viacocrea technology aims to structure, support, enrich and orchestrate cocreative problem-solving. Viacocrea provides to teachers and students with a multi-user collaborative platform and graphic representation of cocreative processes with a set of creative techniques. Viacocrea structures the creative process into the subsequent six non-linear creative phases, namely, Start up; Define; Design; Build Up; Sum up; and Communicate. Readers can have more information about the iconography of the six creative phases promoted in Viacocrea in <https://www.contic.udl.cat/en/project/viacocrea>.

The six-phase cocreative process is enriched with a cocreative toolkit. This toolkit serves a dual purpose: firstly, it offers a range of visual cocreative techniques aimed at expanding the repertoire of cocreative strategies to solve a challenge innovatively. These techniques encompass divergent processes, such as brainstorming; exploratory processes like idea elaboration, and convergent processes, including idea selection. Figure 1 showcases three of these techniques.

Secondly, the cocreative toolkit provides guidance and recommendations about the objective of each cocreative technique, its optimal utilization, and the cultivation of co-creative attitudes conducive to maximizing group

synergy. This guidance is meticulously presented through a combination of video tutorials and infographics, ensuring accessibility and clarity in understanding, and implementing these techniques effectively within collaborative endeavors.

Figure 1
Examples of Creative Techniques - Viacocrea Toolkit



Viacocrea for teachers

Viacocrea offers teachers a rich repository of co-creative projects intricately linked to curriculum topics. Teachers have the flexibility to utilize these projects as they are pre-designed, or they can tailor them to suit their specific needs or even craft entirely new projects. Notably, when a teacher pioneers a new project, it enriches the project repository, making it accessible to fellow educators. The Viacocrea template serves as a comprehensive guide, leading teachers through each stage of project design intended for cocreative student engagement. Teachers have the autonomy to define the project's structure and curate the resources provided to students, empowering them to tackle the project cocreatively. Following project design, teachers can seamlessly assign the project to various student groups, facilitating cocreative problem-solving. Additionally, Viacocrea equips teachers with detailed reports on student progress, enabling them to monitor and provide tailored guidance to each group throughout the project's duration.

Viacocrea for students

Upon logging into the Viacocrea platform, each student will discover the co-creative projects assigned by their teacher. While Viacocrea can be utilized remotely, it has been specifically tailored to foster cocreation in-person interaction. Consequently, students will convene with their group members face-to-face, accessing the multiuser Viacocrea space to engage collaboratively. Within this space, students will embark on an iterative journey, following the phases, techniques, and recommendations meticulously outlined by the teacher to cocreatively tackle the challenge at hand.

During the conference, participants in the tutorial will have the opportunity to experience firsthand how Viacocrea promotes cocreation. Critically engaging with Viacocrea technology, participants will collaboratively explore its advantages and challenges, delving into its potential as a transformative tool for promoting cocreation within authentic classroom settings.

References

Ouyang, F., Wu, M., Zhang, L., Xu, W., Zheng, L., & Cukurova, M. (2023). Making strides towards AI-supported regulation of learning in collaborative knowledge construction. *Computers in Human Behavior*, 142, 107650. <https://doi.org/10.1016/j.chb.2023.107650>.

Richardson, C. (2022). Supporting collaborative creativity in education with the i5 Framework. *Educational Action Research*, 30(2), 297-312. <https://doi.org/10.1080/09650792.2020.1810731>

Sawyer, R. K. (2021). The iterative and improvisational nature of the creative process. *Journal of Creativity*, 31, 100002. <https://doi.org/10.1016/j.yjoc.2021.100002>

Sawyer, R. K. (2022). The dialogue of creativity: Teaching the creative process by animating student work as a collaborating creative agent. *Cognition and Instruction*, 40(4), 459-487. <https://doi.org/10.1080/07370008.2021.1958219>.

Sun, M., Wang, M., Wegerif, R., & Peng, J. (2022). How do students generate ideas together in scientific creativity tasks through computer-based mind mapping? *Computers & Education*, 176, 104359. <https://doi.org/10.1016/j.compedu.2021.104359>



Orchestration Assistant: A Real-time Teacher Guidance Tool

Daeun Hong, Chen Feng, Kelli Paul, Xiaotian Zou, Cindy E. Hmelo-Silver
dh37@iu.edu, carrfeng@iu.edu, kelpaul@iu.edu, xz107@iu.edu, chmelosi@indiana.edu
Indiana University

Seung Lee, Tianshu Wang, Kimberly Farnsworth, Krista Glazewski, Bradford Mott, James Lester
sylee@ncsu.edu, twang43@ncsu.edu, kbfarnsw@ncsu.edu, kdglazew@ncsu.edu, bwmott@ncsu.edu,
lester@ncsu.edu
North Carolina State University

Abstract: In complex and ill-structured learning environments such as computer-supported collaborative learning (CSCL) settings, it is critical for teachers to monitor and understand student learning to make informed decisions on the fly and offer support tailored to their learning situations. To support teacher classroom orchestration and facilitation, we designed a real-time orchestration guidance tool, Orchestration Assistant (OA), to help teachers understand the unfolding learning status, make informed decisions, and provide appropriate and timely scaffolds within a game-based collaborative inquiry environment. Due to the limited studies presenting empirical examples of interface design and features of the tool to support teacher's classroom orchestration and facilitation in real-time within a collaborative inquiry-based game environment, with descriptions of the theoretical frameworks and learning context, this paper aims to introduce the orchestration assistant, describe its design, and discuss our demonstration plan.

Introduction and background

In computer-supported collaborative learning (CSCL) and problem-based learning (PBL) environments, students learn through computer-mediated activities and dynamic interactions with peers, artifacts, and tools embedded. Successful student learning in these complex and ill-structured learning contexts requires teacher support in the form of classroom orchestration (Dillenbourg, 2013). This refers to facilitating classroom activities across multiple social planes (Dillenbourg et al., 2018). As the learning activities, technological tools, artifacts, and peer interactions mediate student learning (Danish & Gresalfi, 2018), how they interact within the learning environment contains meaningful information representing students' understanding, learning progress, and needs. Therefore, for productive classroom orchestration, teachers need to be able to monitor the information of students' learning process to make on-the-fly decisions and provide support tailored to their needs and learning situations. In such learning settings, where students engage in collaborative computer-mediated learning activities, orchestration technology utilizing learning analytics for processing large amounts of student data can assist teachers by making the data accessible and interpretable in real time. Using such a tool, teachers can orchestrate a sequence of activities and interactions that happen within a learning environment based on an informed understanding of students' learning status (Roschelle et al., 2013). We developed a real-time orchestration assistant (OA) to support teachers' management of classroom learning activities occurring at the whole-class, group, and individual student levels for a game-based collaborative inquiry environment. Although previous studies have explored learning design, teachers' perspectives on such orchestration tools, and user experience (e.g., van Leeuwen et al., 2019), limited studies presented empirical examples of interface design and features of the tool to support teacher's classroom orchestration and facilitation in real-time within a collaborative inquiry-based game environment. In this paper, the orchestration assistant (OA) refers to a real-time tool that provides teachers with data visualization of student learning progress, notifications regarding student actions, and instant recommendations for facilitation based on the analysis of student data. In the following sections, we introduce our classroom orchestration tool, illustrate its interface design and features, and propose our demonstration plan.

Theoretical frameworks for the design of an orchestration assistant (OA) tool

In complex learning contexts such as game-based collaborative inquiry, providing teachers with information about their students' learning situations is crucial to diagnosing the current learning situations in a classroom and making informed decisions (Holstein et al., 2020; Loibl et al., 2020). OA, a type of orchestration tool, is a promising tool that leverages learning analytics and visualizations to assist teachers' classroom orchestration and facilitation (Martinez-Maldonado et al., 2019; van Leeuwen et al., 2022) within such complex and ill-structured learning environments. The design of OA is grounded in the three features of an orchestration tool proposed by van Leeuwen and colleagues (2019): 1) *mirroring*, 2) *alerting*, and 3) *advising*. Mirroring is a type of support



providing information regarding student engagement with learning content, which is represented through data visualization. This function allows teachers to attain an accurate up-to-date overview of how their students perform and constantly develop an understanding of learning situations. Alerting helps teachers to notice and detect relevant information that might need their additional or immediate attention. By presenting visual notifications, OA informs teachers of certain identified learning situations that might require teachers' support in response to students' needs and learning status. For instance, when a group has been spending an extended amount of time on a single collaborative learning task, the OA system can send a notification about the group's situation to help a teacher interpret the displayed information, be aware of the group's situation and focus attention on the group. Lastly, advising is a feature that supports teachers by offering them actionable recommendations corresponding to an emergent learning situation. This function empowers teachers to consider diverse facilitation strategies and determine to offer fine-grained prompts and context-specific scaffolding.

Furthermore, drawing upon Verbert's learning analytic model (2013), we identified three types of information that should be showcased in the OA to support teacher facilitation: 1) student *progress*, 2) *participation* in learning activities, and 3) *scientific discussions* during problem-solving processes. Student progress informs task completion and the specific tasks on which students are currently working. Information regarding participation indicates the extent of student contribution to the learning activities, while scientific discussion data reflects the quality of the science conversations among students within a group. Following this, we made additional decisions on the types of student in-game data that could best represent each type of information for real-time processing. For student progress information, we collect students' locations within the game, the amount of time spent on a task, and whether or not students have completed a certain task. To present the information of participation and scientific discussion, OA systems leverage students' chat data throughout or during collaborative problem-solving activities. OA also draws data from students' written responses for exhibiting information about scientific discussion. Specifically, the average number and standard deviation of chatlines inform about student participation. The content of the students' conversations and written responses are used to represent scientific discussion information.

Crystal Island: EcoJourneys

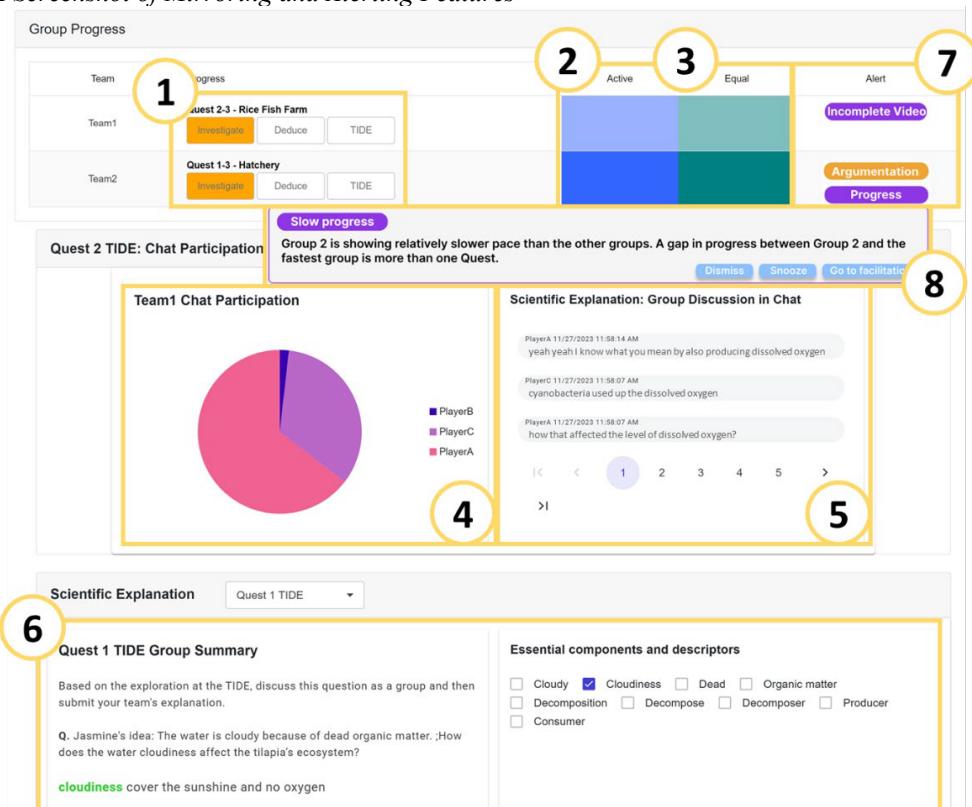
The real-time classroom OA tool is designed to help teachers orchestrate the interactions of multiple small groups within a game-based collaborative inquiry environment, CRYSTAL ISLAND: ECOJOURNEYS, that is incorporated with problem-based learning and game-based learning (Saleh, Hmelo-Silver, Glazewski, Mott, Chen, Rowe, & Lester, 2019). It is designed to develop disciplinary learning in middle school life science and collaborative science inquiry. In the game, three to four students within a small group collaboratively solve an aquatic ecosystem problem about why tilapia fish at a local farm become sick. The game consists of three quests following a tutorial. In each quest, students individually investigate phenomena related to aquatic ecosystems by interacting with in-game characters and objects. Subsequently, they work as a group to engage in collaborative inquiry activities within the game, Deduce and TIDE (*Talk, Investigate, Deduce, and Explain*). At the end of each Deduce and TIDE activity, groups are required to summarize a question about the focal aspect of the phenomena for that quest. Throughout the gameplay, students can communicate using in-game chat, and their in-game actions, such as location, duration, chat, use of tools, etc., are recorded in the game trace log, which serves as data for the OA.

The interface and features of orchestration assistant (OA)

Figure 1 presents three key interfaces of the OA corresponding to mirroring, alerting, and advising functions, which display real-time information on progress, participation, and scientific discussion at multiple social levels. In terms of mirroring (Figure 1), contains information pertaining to (1) each group's specific location in the game [progress] and how (2) actively and (3) evenly each group contributed to chat [participation] throughout the gameplay with color codes. Darker colors indicate less active chat participation, and fewer students contributing to chat participation, respectively. For instance, light blue and dark green colors indicate only a few students (one or two) are talking in the in-game group chat during the gameplay. A selected row in the table presents details on (4) the distribution of chat participation across students within a group [participation]. Additionally, the table presents how they have engaged in collaborative inquiry activities by (5) displaying actual in-game chat that contains relevant scientific argumentation and concepts of the aquatic ecosystem [scientific discussion] and (6) highlighting words relevant to scientific concepts and argumentation in the group's summary answer [scientific discussion]. On the far right side of the table, OA exhibits (7) notifications that might require teachers' additional attention regarding aspects of progress, participation, and scientific discussion (i.e., alerting). In the current version, OA is able to fire eight different notifications (e.g., video incompleteness, slow progress, low chat, scientific elaboration, etc.) across the three types of information. Once a user hits a notification icon, a small window offers

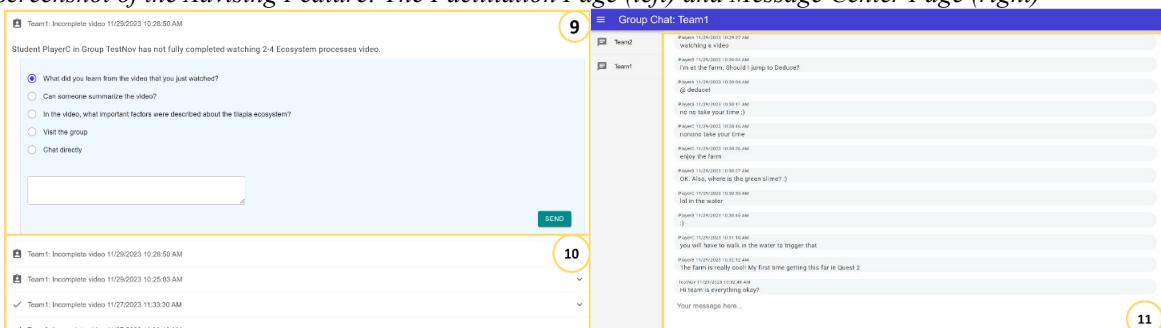
(8) a summary of the situation with buttons directing to the facilitation page and dismissing or snoozing the notification, respectively.

Figure 1
A Screenshot of Mirroring and Alerting Features



Concerning the advising features, on the facilitation page (Figure 2 left), (10) notifications received during the day are listed in chronological order. Users can distinguish whether a notified situation is addressed or not by a check mark. When a user clicks one of the received notifications, (9) several actionable recommendations corresponding to the alerted situation will be presented. Users have the flexibility to select either one of the scaffolding prompts provided by OA, devise their own prompt, or opt to physically visit a group as a facilitation strategy to resolve the situation. Interacting with the OA, teachers can also decide the timing to provide scaffolds and adjust facilitation strategies on their own. On the message center page (Figure 2 right), as part of a feature affording a teacher to scaffold within OA, users are able to directly send messages, which will appear in the group's in-game group chat, anytime as well as monitor students' actual conversations in real-time. As such, OA empowers teachers to gain insights into facilitation strategies and classroom orchestration, make informed decisions, and take effective actions based on their accurate understanding of the learning situation.

Figure 2
A Screenshot of the Advising Feature: The Facilitation Page (left) and Message Center Page (right)



Proposed interactive demo



Our goal is to demonstrate how OA can support teachers in grasping students' learning processes in real-time and provide timely support contingent on students' learning status in diverse learning scenarios. In this demonstration, we will first introduce OA along with background information relevant to it, including the game and the curriculum content, to the participants. We will also provide a brief overview of the major interface and functions of OA and demonstrate the functions. Subsequently, participants will engage with the OA tool, which is populated with simulated student data projecting various scenarios of group dynamics. After exploring the interfaces and reviewing information, participants will be grouped into pairs or small groups to discuss what decisions they might make for classroom facilitation and reflect on their decision-making process based on what they have noticed. Finally, we will return to the whole group, where participants will share what they have discussed and engage in further discussion about the possible future direction of the OA.

References

Danish, J. A., & Gresalfi, M. (2018). Cognitive and sociocultural perspective on learning: Tensions and synergy in the learning sciences. *International handbook of the learning sciences*, 34-43.

Dillenbourg, P. (2013). Design for classroom orchestration. *Computers & education*, 69, 485-492.

Dillenbourg, P., Prieto, L. P., & Olsen, J. K. (2018). Classroom Orchestration. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.), *International Handbook of the Learning Sciences* (pp. 180-190).

Holstein, K., Aleven, V., & Rummel, N. (2020). A conceptual framework for human-AI hybrid adaptivity in education. In *Artificial Intelligence in Education: 21st International Conference, AIED 2020, Ifrane, Morocco, July 6–10, 2020, Proceedings, Part I* 21 (pp. 240-254). Springer International Publishing.

Martinez-Maldonado, R. (2019). A handheld classroom dashboard: Teachers' perspectives on the use of real-time collaborative learning analytics. *International Journal of Computer-Supported Collaborative Learning*, 14(3), 383-411

Roschelle, J., Dimitriadis, Y., & Hoppe, U. (2013). Classroom orchestration: Synthesis. *Computers & Education*, 69, 523-526.

van Leeuwen, A., & Rummel, N. (2019). Orchestration tools to support the teacher during student collaboration: A review. *Unterrichtswissenschaft*, 47(2), 143-158.

van Leeuwen, A., Rummel, N., & Van Gog, T. (2019). What information should CSCL teacher dashboards provide to help teachers interpret CSCL situations? *International Journal of Computer-Supported Collaborative Learning*, 14(3), 261-289.

van Leeuwen, A., & Rummel, N. (2022). Teachers learning to implement student collaboration: The role of data analytics tools. In *Teacher Learning in Changing Contexts* (pp. 35-46). Routledge.

Loibl, K., Leuders, T., & Dörfler, T. (2020). A framework for explaining teachers' diagnostic judgements by cognitive modeling (DiaCoM). *Teaching and Teacher Education*, 91, 103059.

Saleh, A., Hmelo-Silver, C. E., Glazewski, K. D., Mott, B., Chen, Y., Rowe, J. P., & Lester, J. C. (2019). Collaborative inquiry play: A design case to frame integration of collaborative problem solving with story-centric games. *Information and Learning Sciences*, 120(9/10), 547-566.

Verbert, K., Duval, E., Klerkx, J., Govaerts, S., & Santos, J. L. (2013). Learning analytics dashboard applications. *American Behavioral Scientist*, 57(10), 1500-1509.

Acknowledgments

This research was supported by the National Science Foundation through grants IIS-1839966, SES-1840120, and DRL-2112635. Any opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and do not necessarily represent the official views, opinions, or policies of the National Science Foundation. We also thank our collaborating teachers, all of the students who participated in this work, and Inquirium.



TRFlens: A Visual Learning Analytical Tool to Support Teacher Video-Based Reflection and Feedback on Classroom Dialogue

Chao Yang, Gaowei Chen
chaoyang@connect.hku.hk, gwchen@hku.hk
The University of Hong Kong

Abstract: TRFlens is a visual learning analytical tool for supporting *teacher reflection and feedback* on classroom dialogue in video-based professional practices. It provides an interactive, coordinated, and visualized interface for analyzing classroom dialogue and peer feedback for the affordance of teachers' reflective learning. This paper elaborates on the key design process of TRFlens, including the theoretical basis, design principles, and visualization views. In this interactive demo, participants will be guided how the tool supports teacher reflection and feedback through visual analytics of classroom dialogue from a sample video.

Introduction

Teachers' reflective practice is widely acknowledged as an important component of professional development (Mathew et al., 2017). Engaging in reflection on classroom dialogue offers significant insights for teachers to enhance their instructional effectiveness as well as improve student learning outcomes (Chen et al., 2020; Walsh, 2013). Although researchers have investigated video-based reflective tools that were developed to facilitate teacher reflection on teaching practice, there is limited research that combines pedagogical theories and design principles in the tool development process. Moreover, most of the tools ignored the role of peer feedback which can be an important catalyst for collaborative learning and improvement in video-based reflection process.

To address these concerns, this proposal focuses on designing a visual learning analytical tool called Teacher Reflection and Feedback Lens (TRFlens) that aims to enhance teacher reflection and feedback on classroom dialogue during video viewing. It visualizes teachers' classroom talk for self-reflection and tracks how reflective feedback is generated across talk turns, thereby connecting teacher reflection, feedback, and enactment with classroom discourse analytics. In the following, we describe the theoretical basis of our design for the visualization views and plan of next steps.

Theoretical basis

Teachers' orchestration of classroom dialogue plays a significant role in fostering student thinking and learning development, and how to promote dialogic teaching skills remains an unsolved issue for teachers in their professional careers (Kim & Wilkinson, 2019; Resnick et al., 2015). One common solution is through videos, which serve as a powerful tool for teachers to observe and reflect on classroom dialogue. Video enables teachers to deepen understanding of classroom interactions, prompt critical reflection, and facilitate the exchange of peer feedback (Borko et al., 2008; Kleinknecht & Gröschner, 2016). Video-based reflection is based on the framework of "professional vision", which indicates the way teachers utilize contextual and professional expertise to perceive interactions in respect to educational goal (Sherin, 2007; Walsh et al., 2020). Despite the advantages of video in supporting teacher reflection and feedback in their professional practices, they often face the challenges of information overload and easily get lost by unrelated information, which hinders the efficiency of reflection on videos. Moreover, they tend to reflect in an isolated way and lack the opportunity to collaborate with their peers and expert teachers.

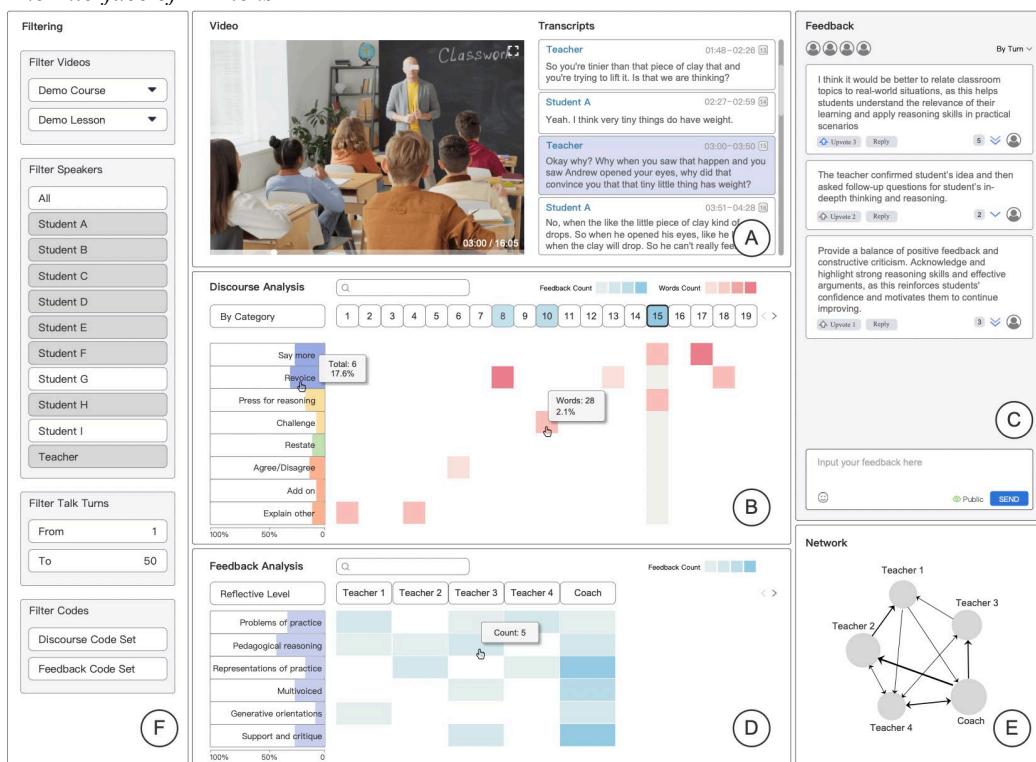
Visualization technologies hold the potential to address these challenges. Scholars have employed visual learning analytics (VLA, Vieira et al., 2018) which utilizes visualizations to represent educational datasets to carry out learning analytical tasks efficiently. To create effective visualizations, Shneiderman (1996) proposed a three-step principle for designing an interactive data visualization system "overview-zoom/filter-details", which clearly explains how a visualization system supports information retrieval. Mazza (2009) argued that effective visualization design should be manipulable and transformable, which allows users to control the view creation process and modify the views generated, and finally get information on demand. Mazza also proposed principles, such as "overview + details", "focus + context", and "data filtering" to optimize the visualization designs.

Visualization designs

Guided by the pedagogical theories and design principles above, we provide six coordinated views in TRFlens: *Video & Transcripts View* (see Figure 1_A) shows the classroom video and transcripts; *Discourse Analysis View*

(see Figure 1_B) shows the visualization of teacher's talk moves and tracks teachers' reflective feedback based on talk turns. We use timeline-based heatmaps to represent the number of words in a talk turn, and set them apart by shade darkness. The darker shade of red in the tiles represents a higher amount of words in a talk turn; *Feedback View* (see Figure 1_C) shows the detailed feedback to the specific talk turn; *Feedback Analysis View* (see Figure 1_D) shows the visualization of feedback from different teachers based on their reflective level; *Network View* (see Figure 1_E) shows the interactions among group members. We use network maps to represent how group members interact with each other by the number of feedback posts. Each node represents a teacher or a coach, and the edge indicates interaction between two members. The node size is proportional to the amount of feedback posts, and the weight of the edges shows the density of two members' interactions; *Filter Panel* (see Figure 1_F) shows the options for data filtering. To evaluate classroom dialogue and teacher feedback, we adopt the framework of academically productive talk (APT, Resnick et al., 2015) and pedagogically productive talk (PPT, Lefstein et al., 2020) in the design of discourse and feedback analysis views (see Figure 1_B and Figure 1_D). By navigating the interface of different views and filtering information on demand to interact with the visualizations, teachers can be supported to reflect on classroom dialogue and collaborate with their peers for group discussion.

Figure 1
The Interface of TRFlens



Interactive demo and next steps

In the interactive demo session, we will present audience the main functions of TRFlens in facilitating teacher reflection and feedback on classroom dialogue. Firstly, we will give a brief introduction of the tool, including the design considerations and functions of different visualization views. Secondly, participants will be invited to join a virtual collaborative group to watch a sample video that has been provided, they will see how the classroom dialogue of the video is visualized by the tool and how teacher feedback is tracked across talk turns. They can interact with the visualizations while watching the video and offer feedbacks. Each participant is required to have one laptop or tablet with internet access. Finally, we will encourage discussions on the affordances and limitations of the tool for teachers to improve their dialogic teaching practice. We hope TRFlens can be a powerful tool for fostering a sense of community and connection among individual teachers, as well as encouraging dialogue, the exchange of different perspectives, and the development of shared values and goals. The next step for this project is to test the usefulness of the tool and to examine its impact on teacher learning and reflection in professional practices.



References

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, 24(2), 417-436.

Chen, G., Chan, C. K., Chan, K. K., Clarke, S. N., & Resnick, L. B. (2020). Efficacy of video-based teacher professional development for increasing classroom discourse and student learning. *Journal of the Learning Sciences*, 29(4-5), 642-680.

Kim, M. Y., & Wilkinson, I. A. (2019). What is dialogic teaching? Constructing, deconstructing, and reconstructing a pedagogy of classroom talk. *Learning, Culture and Social Interaction*, 21, 70-86.

Kleinknecht, M., & Gröschner, A. (2016). Fostering preservice teachers' noticing with structured video feedback: Results of an online-and video-based intervention study. *Teaching and Teacher Education*, 59, 45-56.

Lefstein, A., Vedder-Weiss, D., & Segal, A. (2020). Relocating research on teacher learning: Toward pedagogically productive talk. *Educational Researcher*, 49(5), 360-368.

Mathew, P., Mathew, P., & Peechattu, P. J. (2017). Reflective practices: A means to teacher development. *Asia Pacific Journal of Contemporary Education and Communication Technology*, 3(1), 126-131.

Mazza, R. (2009). *Introduction to information visualization*. Springer Science & Business Media.

Resnick, L. B., Apterhan, C., & Clarke, S. N. (Eds.). (2015). *Socializing intelligence through academic talk and dialogue*. American Educational Research Association.

Sherin, M. G. (2007). The development of teachers' professional vision in video clubs. In R. Goldman, R. Pea, B. Barron, & S. Derry (Eds.), *Video research in the learning sciences* (pp. 383-395). Mahwah, NJ: Erlbaum.

Shneiderman, B. (1996). The eyes have it: A task by data type taxonomy for information visualizations. In *Proceedings 1996 IEEE symposium on visual languages* (pp. 336-343). IEEE.

Vieira, C., Parsons, P., & Byrd, V. (2018). Visual learning analytics of educational data: A systematic literature review and research agenda. *Computers & Education*, 122, 119-135.

Walsh, M., Matsumura, L. C., Zook-Howell, D., Correnti, R., & Bickel, D. D. (2020). Video-based literacy coaching to develop teachers' professional vision for dialogic classroom text discussions. *Teaching and Teacher Education*, 89, 103001.

Walsh, S. (2013). *Classroom discourse and teacher development*. Edinburgh University Press.

Acknowledgments

This work was supported by Hong Kong Research Grants Council, University Grants Committee (Grant No.: 17605221).



DEMO: A Tabletop Action-Based Embodied Design for the Cartesian System

Ilona Hłowiecka-Tańska, Katarzyna Potega vel Żabik
ilona.tanska@kopernik.org.pl, katarzyna.potega@kopernik.org.pl
Copernicus Science Center

Dor Abrahamson, University of California Berkeley, Korea University, dor@berkeley.edu

Abstract: Interactive technology is carving a new frontier in mathematics education by transforming abstract concepts into tangible and collaborative experiences. This DEMO presentation introduces the exhibit, a pedagogical interactive technology wherein visitors learn the coordinate system's basic logico-mathematical principles through collaborative goal-based play. Previous design solutions in this genre of interactive museum exhibits include: *Geometris*, a geometry learning game that combines elements of *Tetris*™ and *Twister*™ (Rosenbaum et al., 2020); *Math Square*, a multi-user exhibit at the National Museum of Mathematics (MoMath), where visitors collectively navigate mathematical challenges (Shoyer, 2018); and, closest to home, *Drawing in Motion*, an exhibit developed by the Oregon Museum of Science and Industry, where two participants collaboratively operate a digitized Etch-a-Sketch, one participant per rotating knob, to draw images on a screen (Nemirovsky et al., 2013). Inspired by this interactive exhibit genre, the solution we aim to present offers further empirical context to evaluate the potential educational significance of leveraging technology to foster intuitive embodied understandings of mathematical concepts.

Coordinate systems: Design problems and solutions

Design problem

Coordinate systems such as the Cartesian coordinate plane are used in many subjects in the fields of mathematics and statistics, natural sciences (e.g., geography, physics), or social sciences (e.g., history). Correctly using Cartesian coordinate systems is essential to understanding graphs, maps, and models. Many students have difficulties analyzing graphs (Bell & Janvier, 1981; Kerslake, 1981; Leinhardt et al., 1990;) and reading maps (Downs & Liben, 1991). We were therefore motivated to ideate the design of activities that would occasion opportunities for students to: (a) become oriented in the Cartesian coordinate system, thus perceiving a point in two-dimensional space as cross-plotted at the intersection of two intersecting orthogonal lines that emanate, respectively, from horizontal and vertical reference axes; and (b) understand the diagrammatic semiotic methodology of ordered-pair notation, for example, being able to encode a given point on the plane as "(5, 3)" and, vice versa, to locate a point marked as such.

Design solution

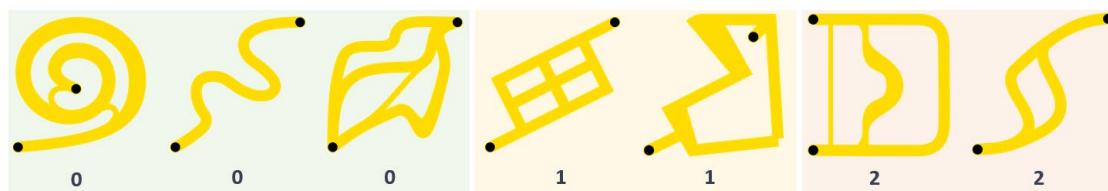
Working in the embodied-design paradigm (Abrahamson, 2014; Abrahamson et al., in press), we strived to model the activity on two ideation heuristics: (1) the enactivist tenet that individuals' cognitive structures emerge from recurring task-effective sensorimotor patterns discovered through explorative perceptuomotor activity (Varela et al., 1991); and (2) cognitive-anthropological theorizations of shared ontologies as emerging through multimodal social interaction to facilitate the coordinated enactment of joint action (Goodwin, 2013). The design resulted in an interactive two-player game, where participants collaboratively control a virtual ball's coordinates to navigate it through maze-like paths, with the objective of completing the course in the shortest time and with the fewest moves. Earlier generations of this design's general mechanics—distributed orthogonal control of a digital object's movement across a Cartesian field—can be found in the Mathematics Imagery Trainer research at the Embodied Design Research Laboratory, University of California Berkeley (Lee et al., 2013) and with their collaborators at Utrecht University (Shayan et al., 2015).

Technical configuration and data collection

The game integrates an interactive module equipped with a Naos+ 86" Multi-Touch Display and operates on Microsoft Windows 11 Pro PL 64-bit OEM, marked by product ID FQC-10544. Intended for educational exhibition at museum learning stations, the unit utilizes software designed to enhance user interaction while gathering data on engagement metrics. Data are collected from each interaction and compiled into files from all

interactions throughout the day, with the files in CSV format being named after the date. The exhibit interaction data are composed of several elements that reflect participants' activity. Data entries are initiated when participants consent to the study. Information about this selection, team identification, and consent status are systematically recorded. The dataset includes the date of participation, the team's code—a combination of the creation date and a unique identifier—and the language preference indicated by the participant. Timestamps are logged for button presses during the study with precision to milliseconds (hour:minute:second.milliseconds). The dataset indicates the team's completion status as true if all three levels are completed successfully. It also records the method of study conclusion, denoting completion either by pressing the "finish" button, returning to the main screen, or resetting after inactivity is detected. Seven track identifiers and associated three levels are noted (see Figure 1), with timestamps marking the start and end of each level attempt, along with the duration in milliseconds. Seven sample paths items groups into three levels (0, 1, 2) that correspond to increasingly mathematized game mechanics.

Figure 1
Seven Sample Paths Items Groups into Three Levels



Data on track completion, errors (e.g., the ball driven off the track), and level completion are tracked. The times at which specific buttons are pressed and the visibility status of the crosshair are recorded. The position of the ball, recorded as X and Y coordinates for each frame, provides insight into the interaction dynamics. The position is measured in pixels, where the origin point (0, 0) in the coordinate system corresponds to the value 0, 0 in pixels, and the point (15, 15) in the coordinate system corresponds to the value 1800, 1800 in pixels. The dataset reflects the ball's status, indicating whether it is in its initial position, has been relocated correctly, has reached the track's end, is off the track due to an error, or has been manually repositioned to a new coordinate following a mistake. This structured data capture allows for detailed subsequent analysis.

The learning with exhibit

At the outset of the interaction, participants are provided with information regarding the game and the ongoing research. Participants are asked to consent to participate in the research study. Following this, we request participants share some basic information about themselves—their age and the nature of their relationship (whether they are familiar with each other). The gameplay then commences. Upon completing a level, players can either attempt the same level again for further practice/better results or advance to the next level. The solution offers multiple maze layouts for each level, which are randomly generated. Each level offers a distinct experience, gradually increasing complexity and requiring players to adapt and collaborate effectively. Here, we provide an overview of the gameplay progression through each levels: 1) Cooperative Coordination, 2) Introduction of Coordinates—Transitioning from Manual to Numerical Control, 3) Full Numerical Control.

Summary: Design challenges for the science center context

The placement of the exhibit within the context of the science center exhibition, unlike school or other educator-facilitated activities, presented distinct challenges that influenced the initial design criteria: 1) Self-Contained Information, 2) Engagement, 3) Minimal Text. Several aspects contribute to promoting equal opportunities within the planned design:

1. Accessibility: Technology designed with accessibility in mind, considering diverse needs such as physical disabilities, language barriers, or cognitive differences. The exhibit's design, minimizing text and relying on visual cues, fosters accessibility for individuals with varying reading abilities or language backgrounds. Additionally, considering accessibility features for individuals with physical impairments ensures that everyone can engage with the exhibit.
2. Inclusivity: The collaborative nature of the exhibit encourages teamwork and engagement among diverse pairs of visitors, promoting social interaction and collaborative learning experiences.



3. Research and Evaluation: Continuous research and evaluation of the effectiveness and impact of interactive technology in education, like the exhibit, should encompass diverse populations. Analyzing how different groups engage with and benefit from such tools helps in identifying potential biases or gaps in learning experiences and ensures that they cater to a wide array of learners.

By integrating these aspects into the design and implementation of educational technology like the OЯTHO exhibit, educational institutions can take significant steps toward promoting equal opportunities and fostering inclusive learning environments for all students.

References

Abrahamson, D. (2014). Building educational activities for understanding: An elaboration on the embodied-design framework and its epistemic grounds. *International Journal of Child-Computer Interaction*, 2(1), 1–16. <https://doi.org/10.1016/j.ijcci.2014.07.002>

Abrahamson, D., Tancredi, S., Chen, R. S. Y., Flood, V. J., & Dutton, E. (in press). Embodied design of digital resources for mathematics education: Theory, methodology, and framework of a pedagogical research program. In B. Pepin, G. Gueude, & J. Choppin (Eds.), *Handbook of digital (curriculum) resources in mathematics education*. Springer.

Bell, A., & Janvier, C. (1981). The interpretation of graphs representing situations. *For the Learning of Mathematics*, 2, 34–42.

Downs, R. M., & Liben, L. S. (1991). The development of expertise in geography: A cognitive-developmental approach to geographic education. *Annals of the Association of American Geographers*, 81(2), 304–327.

Goodwin, C. (2013, 2013/01/01/). The co-operative, transformative organization of human action and knowledge. *Journal of Pragmatics*, 46(1), 8–23. <https://doi.org/10.1016/j.pragma.2012.09.003>

Kerslake, D. (1981). Graphs. In K. M. Hart (Ed.), *Children's understanding of mathematics concepts* (pp. 120–136). London: John Murray.

Lee, R. G., Hung, M., Negrete, A. G., & Abrahamson, D. (2013, April). *Rationale for a ratio-based conceptualization of slope: Results from a design-oriented embodied-cognition domain analysis*. Paper presented at the annual meeting of the American Educational Research Association (Special Interest Group on Research in Mathematics Education), San Francisco, April 27 - May 1.

Leinhardt, G., Zaslavsky, O., & Stein, M. K. (1990). Functions, graphs, and graphing: Tasks, learning, and teaching. *Review of Educational Research*, 60(1), 1–64. <http://dx.doi.org/10.3102/00346543060001001>

Nemirovsky, R., Kelton, M. L., & Rhodehamel, B. (2013). Playing mathematical instruments: Emerging perceptuomotor integration with an interactive mathematics exhibit. *Journal for Research in Mathematics Education*, 44(2), 372–415.

Potega vel Źabik, K., Abrahamson, D. & Ilowiecka-Tańska, I. It Takes Two to OЯTHO: A Tabletop Action-Based Embodied Design for the Cartesian System. *Digit Exp Math Educ* (2024). <https://doi.org/10.1007/s40751-024-00139-8>

Rosenbaum, L. F., Kaur, J., & Abrahamson, D. (2020). Shaping perception: Designing for participatory facilitation of collaborative geometry. In R. Nemirovsky & N. Sinclair (Eds.), On the intertwined contributions of physical and digital tools for the teaching and learning of mathematics [Special issue]. *Digital Experiences in Mathematics Education*, 6(2), 213–232. <https://doi.org/10.1007/s40751-020-00068-2>

Shayan, S., Abrahamson, D., Bakker, A., Duijzer, A. C. G., & Van der Schaaf, M. F. (2015). The emergence of proportional reasoning from embodied interaction with a tablet application: An eye-tracking study. In L. Gómez Chova, A. López Martínez, & I. Candel Torres (Eds.), *Proceedings of the 9th International Technology, Education, and Development Conference (INTED 2015)* (pp. 5732–5741). International Academy of Technology, Education, and Development.

Shoyfer, E., MoMath Hackathon 2018: "Expressions" - Math Square. GitHub. <https://github.com/eshoyfer/momath-math-sq>

Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. MIT Press.

Enhancing Pre-service Teachers' Competence with a Generative Artificial Intelligence-Enhanced Virtual Reality Simulation

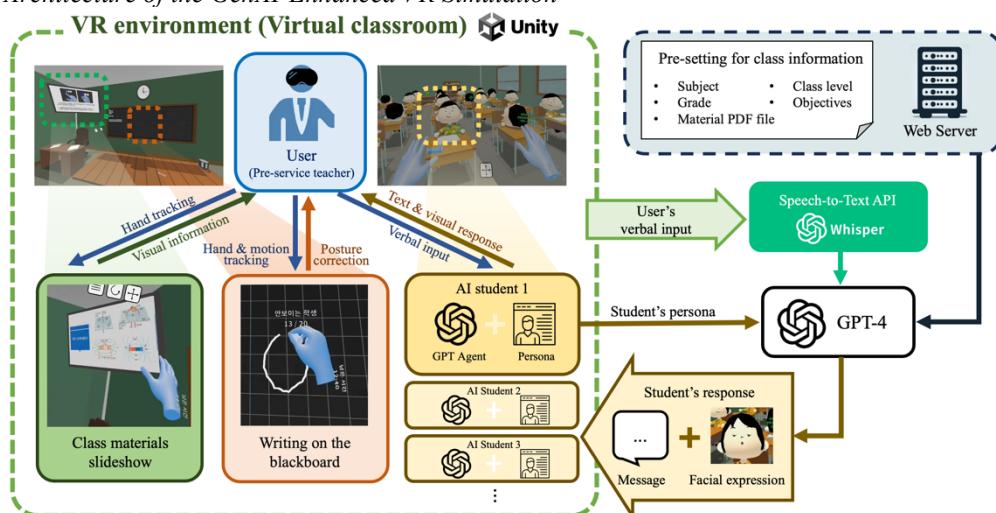
Juno Hwang, Sumin Hong, Taeyeon Eom, Cheolil Lim
 wnsdh10@snu.ac.kr, xiumin@snu.ac.kr, eomcalm@snu.ac.kr, chlim@snu.ac.kr
 Seoul National University

Abstract: This study presents a VR simulation with GenAI-enhanced student agents for pre-service teacher training. Through systematic development, including needs analysis and usability testing, the simulation demonstrates potential in improving teaching competence. The simulation offers authentic teaching and learning situations with AI student. The VR simulation program integrated with GenAI can significantly improve the way for preparing pre-service teachers by providing an immersive, authentic, and personalized learning experience that bridges the gap between theory and practice.

Background

The practicum program for pre-service teachers is a crucial phase where they actively engage in teacher activities and assess their aptitude for the profession (Sim & Kang, 2014). Despite its importance, pre-service teachers often encounter significant challenges—such as instructional design, classroom management, relationship with student, counseling, and managing extracurricular activities (Heo, 2021). Practical training prior to the practicum is essential to address these challenges effectively. In this context, both Virtual Reality (VR) and generative Artificial Intelligence (GenAI) emerge as effective tools to support pre-service teachers' preparation. VR offers an immersive environment where users can actively participate, enabling the replications of complex scenarios that are difficult to experience in conventional educational settings (Chen, 2009; Choi & Kim, 2017; Lee & Kim, 2021). In addition, GenAI gives an intelligent agent that delivers more naturalistic conversational practices. By interacting through direct speech in a VR environment, pre-service teachers can better bridge the gap between abstract educational theories and their practical application (Dale, 1969; Shapiro & Spaulding, 2021). This study aims to develop a VR simulation program integrated with GenAI-enhanced agents, designed to empower pre-service teachers to practice and refine their instructional techniques and skills, ultimately enhancing their teaching competence.

Figure 1
Architecture of the GenAI-Enhanced VR Simulation



Research methodology

Our research employed a systematic approach, outlined as follows. First, we interviewed pre-service teachers who were about to undergo their practicum program to identify problems and requirements. Second, we reviewed existing research to establish the direction of VR simulation program. Third, we developed a simulation scenario,



which was validated for feasibility with in-service teachers. Fourth, we developed a prototype of the VR simulation using Unity and GenAI techniques and conducted three times of usability tests with pre-service teachers. The architecture for the GenAI-enhanced VR Simulation is as shown in Figure 1.

Needs analysis: Interview with preservice teachers

We conducted a needs analysis by interviewing five pre-service teachers who had recently completed their practicum, revealing several key challenges they faced during their teaching experience. The first is their apprehension about having to improvise during lessons. Secondly, they expressed worries about effectively empathizing with learners in a counseling context. A third concern involves the challenge of preparing to teach unfamiliar topics. In addition, due to limited experiences in student guidance, these teachers are apprehensive about their ability to conduct question-and-answer skills with students and manage group activities in an effective manner. Lastly, classroom management emerged as a significant area of concern. Before embarking on their teaching practicum, pre-service teachers need a platform to interact with students and experience various classroom scenarios.

Literature review

We conducted a literature review. This included searches in databases such as Scopus, Web of Science and ProQuest Central using keywords like "virtual reality," "simulation," "pre-service teachers", "preservice teachers", and "practicum". We aimed to identify the challenges faced by pre-service teachers during their practice experiences. Studies have shown that pre-service teachers often struggle with lesson planning, student interaction, and behavior management when immersed in real classroom environments (Mutlu, 2014; Ulla, 2016). We also evaluated the primary goals of current virtual reality simulations and the type of situational learning they offer to achieve these goals. VR simulations primarily focus on practicing specific teaching methods or classroom management techniques (Billingsley et al., 2019; Lindberg & Jönsson, 2023; Lugrin et al., 2016; Theelen et al., 2019). However, most of these simulations are rule-based, offering limited scenarios and responses, which may restrict pre-service teachers' exposure to the diverse and dynamic situations they might encounter in actual classrooms. To overcome these limitations, GenAI and large language model (LLM) like GPT can be leveraged to create more realistic and dynamic simulation environments. GPT's advanced natural language understanding, and generation capabilities enable authentic dialogues and interactions with AI agents (Park et al., 2023).

Development of scenario and personas

The scenario is designed according to Gagné's nine instructional events, including gaining attention, informing learners of objectives, and recalling of prior learning, with missions structured at each event. We then sought feedback from five in-service teachers to verify the scenario's validity, particularly evaluating its usefulness, universality, difficulty, realism, and comprehensibility. By incorporating the valuable insights from experienced teachers, the simulation can more accurately represent the challenges pre-service teachers may face in real classrooms.

In addition to the scenario, we developed the GenAI-enhanced agents, AI students, to populate the virtual classroom. These personas were designed to exhibit diverse characteristics, including different personalities, and backgrounds. We used GenAI, especially GPT-4, to generate authentic personas, ensuring that the AI students could engage in realistic conversations and react appropriately to the pre-service teachers' actions. The AI students' authentic dialogues and responses, generated by GPT-4, allowed for realistic conversations to the pre-service teachers' speech. The combination of scenario and realistic AI student personas aimed to provide pre-service teachers with an immersive and authentic learning experience.

Development of a prototype and usability test

We developed a VR simulation prototype using Unity and integrated the scenario and AI students enhanced with GPT-4. The prototype was then subjected to a series of usability tests across three rounds—Involving five pre-service teachers recently engaged in practicum. Following the initial test, we integrated hand tracking technology, enabling users to use their hands as controllers, enhancing the immersive experience. The second round of testing brought to light the need for more interactive elements; consequently, we enhanced the AI students, with facial expressions and programmed them to occasionally initiate conversations. In addition, we introduced a feature allowing users to select their teaching subject and integrate PowerPoint slides into their lessons. The final usability test was crucial in refining the agents' responses and deciding what to add to their personas, significantly improving their realism. The iterative development process, involving multiple phases of testing and refinement, was crucial in creating a high-quality, user-friendly VR simulation that effectively supports pre-service teachers in developing their teaching skills and confidence.

Figure 2
Screenshots from the GenAI-Enhanced VR Simulation



Outcome

In developing our VR simulation program, we focused on creating an immersive and interactive learning environment for pre-service teachers, aimed at boosting their teaching competence and classroom management skills. Key features of simulation are following:

Mission-based simulation

The VR simulation adopts a mission-based approach, providing pre-service teachers with a series of targeted missions that help them develop essential teaching skills. Each mission is designed to address specific challenges that teachers commonly face in real classrooms. By completing missions, pre-service teachers gain practical experience in handling common classroom situations, such as managing distractions and creating an engaging learning environment. The mission-based simulation approach allows pre-service teachers to focus on developing specific skills in a structured and progressive manner. As they advance through the missions, they build confidence and competence in their teaching abilities. For example, the scenario for Gagné's event of gaining attention is as follows:

- Mission 1: Engage distracted students at the start of the lesson and begin the class.
- Situation: As the pre-service teacher enters the classroom, they find several students asleep. The rest of the students are waiting for the lesson to start. As the lesson begins, the teacher must capture the attention of all students and create an engaging learning environment.
- Objective: Gain the attention of all students, create an engaging atmosphere, and smoothly transition into the lesson.

GenAI based personas

We created five student personas using GPT-4, each with distinct characteristics defined by their gender, academic performance, personality, and career aspirations. For instance, Sumin, one of the student agents, has average academic scores and shows more interest in her teacher than in the class. She frequently asks for the teacher's social media ID. Despite her lack of enthusiasm for the class, she engages actively in class to build a positive relationship with the teacher. When the pre-service teacher asks a question, Sumin might respond with a partially correct answer and then ask for the teacher's opinion on a related topic, demonstrating her desire for interaction with the teacher.

These AI characters are powered by GPT-4, a LLM that enables the generation of realistic and contextually relevant responses. GPT-4 allows the AI students to engage in natural conversations and react appropriately to the pre-service teachers' actions, enhancing the authenticity of the simulation. This feature is believed to enhance the users' ability to handle real-world classroom dynamics.

User input and customization

Pre-service teacher can personalize each session by inputting details such as the subject matter, student level, session duration, and learning objectives of class. They can also upload PDF file and input previous lesson content to update AI students' prior knowledge. This customization—easily managed through a synchronized web platform—ensures that each session in simulation meets the users' specific needs and goals. The web platform provides a user-friendly interface that allows seamless integration of user inputs into the VR simulation, enhancing the overall user experience.

Advanced VR environment

The program leverages advanced VR technologies to provide pre-service teachers with a realistic and engaging experience, allowing them to practice their teaching skills in a safe and controlled virtual space. One key feature



is the intuitive hand tracking system, which enables seamless and natural interaction within the VR environment. Pre-service teachers can manipulate objects by simply pinching them and use a virtual watch display to track session time. This feature significantly enhances the immersive experience and allows pre-service teachers to practice writing on a blackboard with virtual chalk. Additionally, the program monitors the pre-teacher's posture and provides feedback on how many students can read the blackboard without being distracted by the teacher's stance.

Another crucial aspect of the VR environment is its advanced speech recognition capability, which leverages OpenAI's Whisper. This enables the program to deliver realistic interactions with the AI students. Users can engage in natural conversations with the AI students, asking questions, providing explanations, and responding to inquiries. The speech recognition system accurately transcribes the user's speech, facilitating seamless communication between the pre-service teacher and the AI students. Together, these features create a highly immersive and interactive environment that enables pre-service teachers to practice and refine their teaching skills effectively.

Discussion

The VR simulation program integrated with GenAI-enhanced agents can significantly improve the way we prepare pre-service teachers by providing an immersive, realistic, and personalized learning experience that bridges the gap between theory and practice. The integration of AI-powered agents enables authentic, context-specific interactions, simulating the complex dynamics of real-world student behavior. During practice sessions, the system gathers various multimodal data, including recorded and transcribed dialogues between users and GenAI-enhanced agents, eye contact frequency with the agents, and user movement within the virtual classroom. Pre-service teachers can review their simulation results, which include session information, behavioral data, and performance metrics representing their instructional competencies. This is expected to allow pre-service teachers to reflect on their own and assist in improving future lessons.

References

Billingsley, G., Smith, S., Smith, S., & Meritt, J. (2019). A systematic literature review of using immersive virtual reality technology in teacher education. *Journal of Interactive Learning Research*, 30(1), 65-90.

Chen, C. J. (2009). Theoretical Bases for Using Virtual Reality in Education. *Themes in Science and Technology Education*, 2(1-2), 71-90.

Choi, H., & Kim, S. (2017). A research on metaverse content for history education. *Global Cultural Contents*, 26, 209-226.

Dale, E. (1969). *Audio-Visual Methods in Teaching*. Dryden Press.

Heo, S. (2021). What were difficulties of student-teachers during teaching practice? *The Journal of Learner-Centered Curriculum and Instruction*, 21(23), 19-35.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.

Lee, J. & Kim, Y. (2021). A study on the immersive metaverse system to improve the concentration of education. *The e-Business Studies*, 22(6), 3-14.

Lindberg, S., & Jönsson, A. (2023). Preservice teachers training with avatars: A systematic literature review of "Human-in-the-Loop" simulations in teacher education and special education. *Education Sciences*, 13(8), 817.

Lugrin, J., Latoschik, M.E., Habel, M., Roth, D., Seufert, C., & Grafe, S. (2016). Breaking Bad Behaviors: A New Tool for Learning Classroom Management Using Virtual Reality. *Frontiers in ICT*, 3, 26.

Mutlu, G. (2014). Challenges in practicum: Pre-service and cooperating teachers' voices. *Journal of Education and Practice*, 5(36), 1-7.

Park, J., O'Brien, J., Cai, C., Morris, M., Liang, P., & Bernstein, M. (2023). Generative agents: Interactive simulacra of human behavior. *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology*, arXiv:2304.03442.

Shapiro, L., & Spaulding, S. (2021). *Embodied Cognition*, *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University.

Sim, S. & Lee, K. (2014). Effect of teaching practicum for pre-service mathematics teachers' perception changes about teacher's knowledge. *The Mathematical Education*, 54(4), 351-363.

Theelen, H., van den Beemt, A., & den Brok, P. (2019). Classroom simulations in teacher education to support preservice teachers' interpersonal competence: a systematic literature review. *Computers & Education*, 129, 14-26.

Ulla, M. B. (2016). Pre-service teacher training programs in the Philippines: The student-teacher practicum teaching experience. *EFL Journal*, 1(3), 235-250.



We're in This Together (WIT): Leveraging Mixed Reality to Explore Complex Systems

Dan Roy, danroy@education.mit.edu

Sharleen Loh, lohsharleen@gmail.com, Teachers College, Columbia University

Daniel Wendel, Aditi Wagh
djwendel@mit.edu, awagh@mit.edu
Massachusetts Institute of Technology

Abstract: Participatory simulations have been found to support exploration and learning of complex systems. This proposal describes our ongoing design of a technology platform for the design of classroom-based mixed reality participatory simulations that engages students in inquiry within complex systems. Here, we provide a glimpse into the design of one p-sim for students to explore weather dynamics. We also describe the design of the technology platform itself and our vision for it going forward.

Introduction and theoretical background

Complex systems perspectives have made possible many of the breakthroughs and challenges of this century (Thurner et al., 2018). Simply described, complex systems thinking involves investigating how interactions between elements of a system can give rise to aggregate level patterns. Research has shown that adopting a complex systems perspective to reason about scientific phenomena can be challenging for students (e.g., Wilensky & Resnick, 1999). Although we operate in multiple complex systems every day, these properties are often not "visible" to us. Participatory simulations have been found to support learning about complex systems (e.g., Rates et al., 2016).

The vision of this learning technology is to leverage immersive, headset-enabled collaborative mixed reality (MR) to transform classrooms of the near future into a participatory simulation (p-sim) for collaborative investigation of scientific phenomena from a complex systems perspective. Through the power of passthrough AR in the Quest 3 or similar VR headsets, a physical space such as a classroom will turn into an MR system of systems (a system consisting of multiple interconnected systems) for student investigation. Adopting a specific role, students will enter a virtual world representing a global system where they can move freely, access hidden layers of information, collaborate with other student-roles to probe and manipulate their local system, and observe shared outcomes. As students coordinate their emerging understandings with others in class, their explorations challenge them to reason about the phenomenon from a complex systems perspective: The futility of focusing solely on their local system will lead students to see interconnections across their local systems.

Design

We're in this Together! (WIT) capitalizes on recent technological developments in MR to design an immersive participatory simulation (p-sim) experience for complex systems learning in middle school classrooms. The WIT p-sim unfolds in a shared immersive world organized as a system of systems. Students can use "tangible" virtual objects to act on the system by probing or manipulating it from multiple perspectives. These objects are intended to help to organize students' attention and sense making in the environment (e.g., Enyedy et al, 2015). To prototype WIT's functionalities and applicability as a system for students to engage in sense-making of a complex system, we are developing two p-sims: (1) a weather p-sim centered on air masses and fronts and (2) an ecosystems p-sim centered on mutualistic animal relationships. As an illustrative example, we detail the design of the weather p-sim.

Exploring weather dynamics in a p-sim

This p-sim encourages students to explore the complex system of atmospheric interactions between air pressure, moisture, topography, and temperature. The p-sim transforms the classroom into a room-sized map projection of an Earth-like world. Large 3D air masses float across the map, colliding with each other to form weather fronts that precipitate or storm. The objective for a participating class of students is to create a "Goldilocks" zone at the center of each region, with moderate temperature and precipitation, and minimal natural disasters. However, as the regions are interconnected globally, student actions in one region may inadvertently affect the weather in others. Students must work together and communicate between regions, to investigate and respond to the dynamics of the weather across the system.

To do this, groups of 4-6 students are assigned to a continental region of the world. Within their group, students can modify the air pressure system by placing a limited number of high- and low-pressure systems within their assigned region. In this simplified system modeling weather dynamics, high-pressure systems repel air masses, whereas low-pressure systems attract them. For example, students may place a low pressure system in their region to attract air masses to collide and precipitate. However, adding too many low pressure systems may result in cyclones. Students can also modify the topography by raising or lowering land to create different landforms (e.g. mountains, valleys, plains, islands). Topography affects air masses in different ways. For example, mountains may force air masses to flow over them, decreasing temperature and causing precipitation.

Our current prototype enables students to place pressure systems, mountains, and lakes to influence the movement of air masses and impact weather. Air masses move through the simulation and adjust their variables (velocity, temperature, humidity) depending on the temperature of the terrain they are over, the landforms they pass, and their proximity to high or low pressure systems. Air masses precipitate depending on conditions such as relative humidity and temperature differences as they collide and interact. An affordance of being in an MR environment is that students can manipulate spatial aspects of this system in 3 dimensions. This enables an investigation of how air masses rise or sink below each other to create different weather conditions, how they are affected by pressure, and how landforms of different altitudes affect air masses. From a complex systems perspective, students explore how changing a system's constituent parts and properties (e.g., pressure systems & topography) impacts it overall (e.g., precipitation levels).

Figure 1
Students Can Place Pressure System Objects to Influence the Movement of Air Masses to Modify Frequency of Precipitation



The technology platform and future work

The platform is built in Unity using the Oculus VR (OVR) library and Meta Presence Platform API for mixed reality, and Photon engine for multiplayer synchronization. OVR provides video passthrough headset-based 3D rendering functionality, and the Presence Platform provides spatial anchoring, room awareness, and hand tracking. Unity uses a component-based programming pattern in which individual entities (GameObjects) are given MonoBehaviors, a connected set of properties and functions, much like BehaviourComposer (Kahn, 2007). GameObjects with their set of behaviors can then be saved as reusable Prefabs which can be instantiated, akin to agents in an ABM environment. We have developed several Prefabs—such as buttons, levers, and data display panels—and MonoBehaviors such as “grabbable” and “avoid walls”. Our upcoming work involves filling out these collections to create what we consider to be the operational primitives of this p-sim platform.

References

Enyedy, N., Danish, J.A. and DeLiema, D. (2015) 'Constructing liminal blends in a collaborative augmented-reality learning environment', *International Journal of Computer-Supported Collaborative Learning*, 10(1), pp. 7–34. Available at: <https://doi.org/10.1007/s11412-015-9207-1>.

Kahn, K. (2007, July). Building computer models from small pieces. In *SCSC* (pp. 931-936).

Rates, C. A., Mulvey, B. K., & Feldon, D. F. (2016). Promoting conceptual change for complex systems understanding: Outcomes of an agent-based participatory simulation. *Journal of Science Education and Technology*, 25, 610-627.

Thurner, S., Hanel, R., & Klimek, P. (2018). *Introduction to the theory of complex systems*. Oxford University Press.

Wilensky, U., & Resnick, M. (1999). Thinking in levels: A dynamic systems approach to making sense of the world. *Journal of Science Education and technology*, 8, 3-19.

Acknowledgements

This work has been supported by NSF Award DRL-2202431.



Tangible ScratchJr

Jessica Blake-West, Marina Bers

Jess.blake-west@bc.edu, marina.bers@bc.edu

Boston College, Lynch School of Education and Human Development. MA, USA

Abstract: The need for developmentally appropriate tools in early childhood computer science education has increased greatly in the past decade, as technology becomes further integrated into our daily lives. ScratchJr is a programming environment designed for children ages 5-7 and incorporates playfulness, open-ended exploration, and early literacy concepts into the user experience to meet the needs of young users. In this session, we introduce Tangible ScratchJr, an adapted version of ScratchJr currently in development. Tangible ScratchJr goes beyond the digital realm by incorporating an off-screen programming component with physical blocks, effectively creating a multisensory learning experience for young children. This Hybrid User Interface (HUI) not only enhances hands-on learning and making but also introduces valuable screen-free time to complement the digital affordances of ScratchJr.

Introduction

With society's increasing reliance on technology, there is a growing need for effective computer science education. In the past decade, there has been a push to promote coding in early childhood education, creating a need for the design of developmentally appropriate, effective learning tools (Bers, 2018; Bers et al., 2022). Hands-on learning, such as working with tangible manipulatives, has been shown to be an effective learning method for young children (Evangelou et al., 2010), and there have been many efforts to incorporate tangible learning into early childhood computer science education (González-González et al., 2019). Many of the tangible programming technologies currently available come at a high cost and/or are not designed with an accompanying pedagogy and curriculum (Bakala et al., 2022). ScratchJr, currently a digital programming interface, is a free app used worldwide, with over 40 million users. In addition, ScratchJr has over 60 hours of research-based curricula for both teachers and students (Blake-West & Bers, 2023a). ScratchJr is a developmentally appropriate programming environment because it encourages playful, open-ended engagement, and caters to a wide range of developmental needs due to its low floor, high ceiling design (Blake-West & Bers, 2023b). Despite these affordances, ScratchJr is a digital environment and therefore lacks a tangible component to engagement. Tangible ScratchJr, a new version of ScratchJr still in prototype phase, is being developed to meet this need. There is limited research in hybrid user interfaces, such as this one (Antle & Wise, 2013). Through our iterative design process, we will be able to incorporate real-world testing and feedback, which in turn ensures that the final product will align with practical requirements of educators and effectively address the identified gap in HUI technologies for early childhood education.

Overview of Tangible ScratchJr

Tangible ScratchJr is an adapted version of ScratchJr, which retains all computational and creative power of the digital app, while also allowing users to engage in hands-on, screen free programming. The off-screen portion of Tangible ScratchJr is a set of physical blocks, almost identical to the digital ScratchJr programming blocks. They retain the puzzle piece shape of the blocks, and because they are physical blocks, they snap together as the digital pieces are supposed to convey. One of the key innovations driving Tangible ScratchJr is the incorporation of Aruco Markers on each physical block. These markers, resembling small QR codes, serve as a bridge between the physical and digital realms, facilitating a smooth transition of programming sequences in which children can take pictures of their physical programs and upload them to the digital interface (see Figure 1). This decision was rooted in our pedagogical approach, aiming to make the translation from physical to digital blocks explicit for children. By opting for Aruco markers over other options, such as object recognition algorithms or NFC tags, we provided children with an additional layer of comprehension and an opportunity to engage with a technological language in a more tangible manner.

Figure 1

Tangible ScratchJr in Action



The physical blocks can be made in many ways. We have open-source designs for both 3D printing and laser cutting, as well as printable paper versions, and stencils intended to facilitate cardboard (or any other material) cutting to keep the “maker” aspect accessible to those that may not have access to advanced maker technologies. All homemade blocks can be made compatible with the app, all users need is the printable sticker sheets with each blocks’ accompanying Aruco marker.

The Tangible ScratchJr app interface and the design of the physical blocks have both been developed through an iterative process which incorporated children’s feedback on the prototype throughout the process. Additionally, Tangible ScratchJr has undergone initial pilot testing, and we are currently in the process of designing multiple implementation studies. A key finding from piloting was that we discovered a strong preference by many children to create their own blocks using our stencil designs, cardboard, and markers, which we are now leveraging in the Tangible ScratchJr experience as we incorporate the new tool into our ScratchJr curricula. In our upcoming implementation studies, we will compare the effects of Tangible ScratchJr on student engagement, classroom collaboration, coding skill acquisition, and computational thinking abilities. In these studies, we plan to introduce ScratchJr and Tangible ScratchJr to two different classrooms using the Coding as Another Language Curriculum for ScratchJr (Bers et al., 2023a, Bers et al., 2023b; Bers & Yang, 2023; Yang et al., 2023).

Applications of Tangible ScratchJr

Tangible ScratchJr has multiple applications, all of which improve an aspect of accessibility to the ScratchJr experience. The use of physical blocks expands engagement opportunities to those that may face challenges with engaging with a touch screen, specifically those that are visually impaired or struggle with fine motor skill development. Additionally, Tangible ScratchJr extends its reach beyond individual accessibility challenges to foster inclusivity in classroom settings. By offering the flexibility to create homemade blocks, Tangible ScratchJr becomes a valuable resource for classrooms with limited device access. This inclusivity ensures that the benefits of Tangible ScratchJr are not confined to a specific technological infrastructure but can be embraced by a wide spectrum of educational settings.

Contributions of Tangible ScratchJr to the learning sciences

While there are many contributions to the field that incorporate tangible programming, Tangible ScratchJr contributes to the smaller pool of hybrid user interfaces (Antle & Wise, 2013). With ScratchJr’s worldwide reach and established effectiveness (Bers et al., 2023a; Bers et al., 2023b; Yang & Bers, 2023; Yang et al., 2023), Tangible ScratchJr offers a valuable opportunity to observe the effects of introducing a hybrid model on a global scale. This global observational approach allows us to isolate the modification factor introduced by Tangible ScratchJr, facilitating a precise and comprehensive measurement of the effectiveness of hybrid user interfaces in contrast to traditional graphical user interfaces.

Additionally, Tangible ScratchJr introduces a maker component to the programming experience. By enabling users to create their own physical blocks through various accessible methods, Tangible ScratchJr not only enhances engagement but also instills a “maker” ethos. This hands-on approach empowers learners to become active contributors to their learning journey, fostering a sense of ownership and creativity in the programming experience.



Interactive demo session

In this session, participants will be given the chance to try out different variations and iterations of physical blocks, as well as make their own blocks with our block stencils and Aruco marker sticker sheets. Participants will then be given the chance to test the prototype and upload their physical programs into the digital space, where they can further customize their projects or elaborate on their programs.

References

Bakala, E., Gerosa, A., Hourcade, J. P., Tejera, G., Peterman, K., & Trinidad, G. (2022). A Systematic Review of Technologies to Teach Control Structures in Preschool Education. *Frontiers in psychology*, 13, 911057. <https://doi.org/10.3389/fpsyg.2022.911057>

Bers, M. U. (2018). Coding and Computational Thinking in Early Childhood: The Impact of ScratchJr in Europe. *European Journal of STEM Education*, 3(3), 08. doi:10.20897/ejsteme/3868

Bers, M., A. Strawhacker & A. Sullivan (2022), “The state of the field of computational thinking in early childhood education”, OECD Education Working Papers, No. 274, OECD Publishing, Paris, <https://doi.org/10.1787/3354387a-en>.

Bers, M. U., Levinson, T., Yang, Z., Rosenberg-Kima, R. B., Ben-Ari, A., Jacob, S., Dubash, P., Warschauer, M., Gimenez, C., Gonzalez, P., & Gonzalez, H. (2023a). Coding as Another Language: An International Comparative Study of Learning Computer Science and Computational Thinking in Kindergarten. In P. Blikstein, J. van Aalst, & K. Brennan (Eds.), *17th International Conference of the Learning Sciences (ICLS)* (pp. 1659–1665). <https://2023.isls.org/proceedings/>

Bers, M. U., Blake-West, J., Kapoor, M. G., Levinson, T., Relkin, E., Unahalekhaka, A., & Yang, Z. (2023b). Coding as another language: Research-based curriculum for early childhood computer science. *Early Childhood Research Quarterly*, 64, 394–404. <https://doi.org/10.1016/j.ecresq.2023.05.002>

Blake-West, J., & Bers, M. U. (2023a). ScratchJr Connect: Sharing resources for digital making around the world. Montréal, QC, Canada: International Society of the Learning Sciences.

Blake-West, J. C., & Bers, M. U. (2023b). ScratchJr design in practice: Low floor, high ceiling. *International Journal of Child-Computer Interaction*, 37. <https://doi.org/10.1016/j.ijCCI.2023.100601>

Evangelou, D., Dobbs-Oates, J., Bagiati, A., & Choi, J. Y. (2010). Talking about artifacts: Preschool children’s explorations with sketches, stories, and tangible objects. *Early Childhood Research & Practice*, 12 (2), 1–16.

González-González, C. S., Guzmán-Franco, M. D., & Infante-Moro, A. (2019). Tangible technologies for childhood education: A systematic review. *Sustainability*, 11(10), 2910.

Yang, Z. & Bers, M. (2023). Examining gender difference in the use of scratchjr in a programming curriculum for first graders. *Computer Science Education*.

Yang, D., Yang, Z., & Bers, M. U. (2023). The efficacy of a computer science curriculum for early childhood: evidence from a randomized controlled trial in K-2 classrooms. *Computer Science Education*, 1-21.

Learning Along Digital Lines: Using Structure from Motion to Analyze Place-Based Trajectories in Virtual Reality

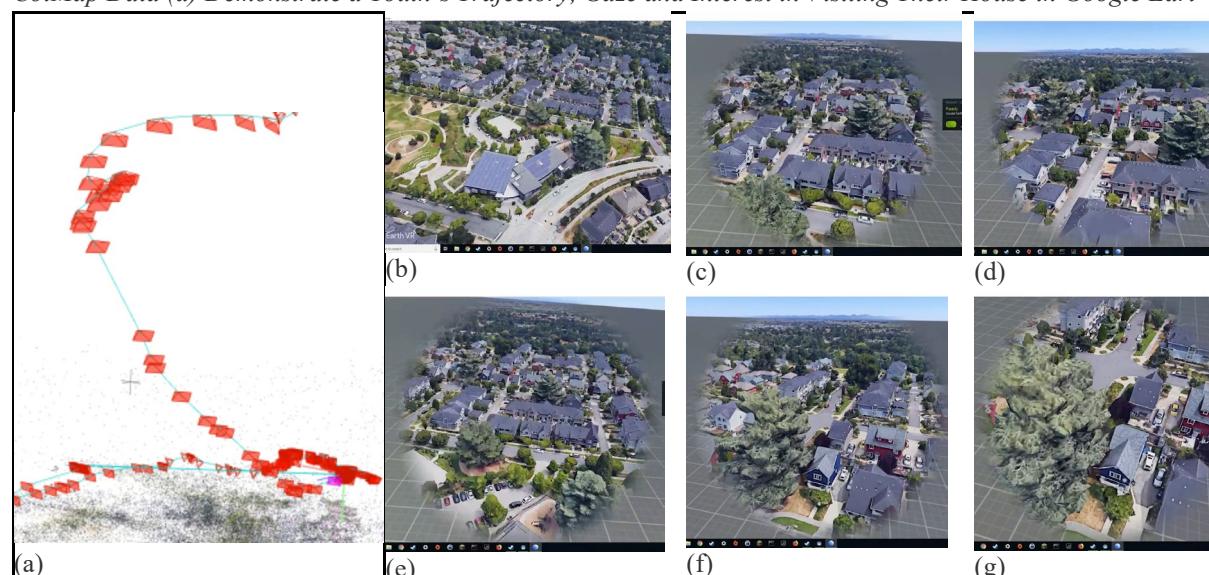
Erin Riesland, Katie Headrick Taylor
 erinsage@uw.edu, kht126@uw.edu
 University of Washington

Abstract: We present a novel way to use ColMap, an open-source application that uses *structure from motion* to extract information from 2D video to produce 3D data models. Using video collected from young people's digital trajectories through their neighborhood in Google Earth, we used ColMap to produce lines of learning and engagement by connecting still image frames to trace youths' location, trajectory and gaze. These lines provided visual data to compare with analog interactions and bridge analog/digital place-based analysis.

Learning-on-the-move (LoM) investigations have largely focused on bodies in places and spaces (Marin et al., 2020), but what about digital places? In this tools demo, we build upon the *learning-along-lines* LoM framework to investigate young people's emergent digital engagement with the city (Taylor, 2017). By following lines of movement through an immersive version of Google Earth, we aimed to understand how youth interacted and engaged with digital representations of their lived, everyday analog environment. Screen recordings of youths' encounters in virtual reality (VR) traced lines of travel, gaze and areas of attention they controlled via a combination of embodied movement and handheld controllers. These screen recordings captured first-person perspectives as they moved through familiar digitally immersive representations of their neighborhood and surrounding environment. However, mapping trajectories of VR movement proved challenging as youth could hover, fly and drop down into the environment in ways not possible in the analog world. To analyze the digital data from youths' headset videos, we applied the open source computer vision application *ColMap* to our screen recorded video data. *ColMap* uses *structure from motion*, a process that extracts spatial information from 2D video to approximate the location of the camera (or operator of the camera) in a reconstructed space (Fisher et al., 2020). We used a customized build of *ColMap* to visually produce lines of movement from first-person perspectives via VR headset video. Neighborhood middle and high school youth provided the video data which was then converted by *ColMap* into a series of line-connected still image frames that highlighted youths' location, trajectory and gaze. (See Figure 1.)

Figure 1

ColMap Data (a) Demonstrate a Youth's Trajectory, Gaze and Interest in Visiting Their House in Google Earth

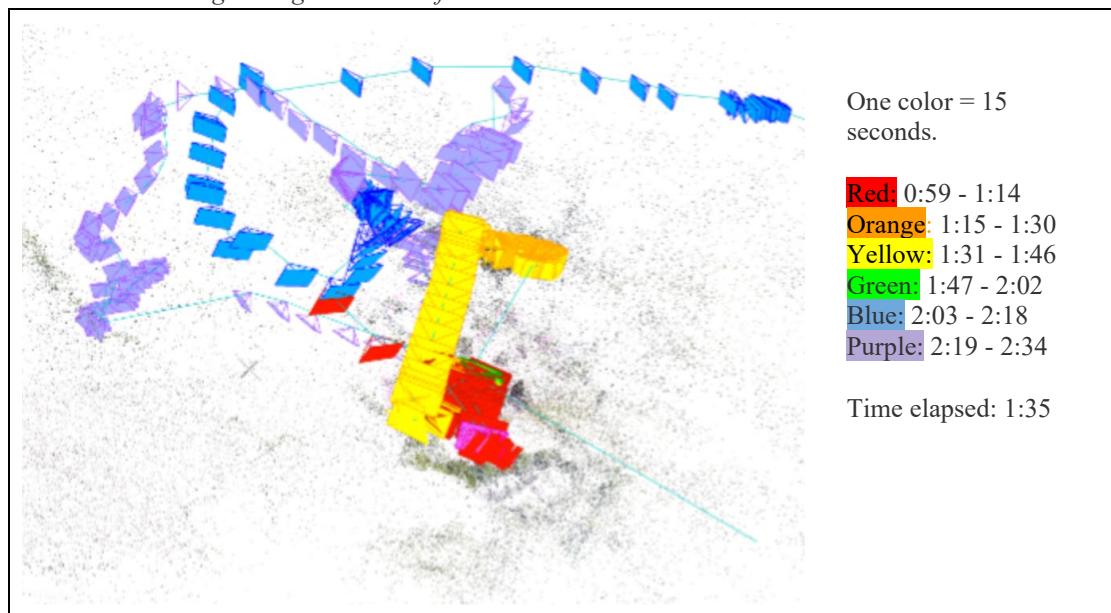


Background

ColMap was originally built to recreate analog space and movement through video data, but as we found can also be used in digital immersive environments as well. We modified the standard ColMap build to include lines of movement through space and allow for color-coding and frame-by-frame analysis (Riesland, 2023). To capture youth interactions in Google Earth VR, we used an HTC Vive running Google Earth VR. We then captured youth's headset video via a screen recorder into an MP4 format. Using FFmpeg to process the video, we exported numbered still frames at 30 seconds per frame. These frames were then imported into our ColMap build to produce an interactive, 3D model of each youth's trajectory along lines (Figure 1a.). For analytical purposes, we modified the open source ColMap code to color specified frame ranges in order to identify areas of interest (Figure 2.), and made the code available to download and install (<https://github.com/samr/colmap>).

Figure 2

Youth's Path through Google Earth VR from 0:59 to 2:34



Possible Applications

The proposed usage of ColMap answers recent calls for new methods of learning and research that address our digital futures. Emergent learning contexts are increasingly built upon recursive interdependent systems impacted by advances in networking, ubiquitous computing, artificial intelligence and immersive realities (Ross, 2022), increasingly blurring lines between digital/analog dichotomies. The confluence of online/offline environments further highlights the complexity between activity systems (Engeström, 1987) that are culturally situated and interdependent. Lines that cross analog and digital barriers offer insights into the digital lives of youth and what holds them as they move in and across settings (Vossoughi et al., 2022), as well as everyday challenges and opportunities that inform youths' daily place-based practices (Taylor, 2017). However, tracing complex interactions that span analog and digital spaces is difficult to visualize and analyze, yet past efforts using GPS traces coupled with GoPro video (Taylor, 2017) and interaction geography methods (Shapiro et al., 2017) have resulted in promising new ways to think about how people engage with the environment.

We continue in this tradition by using ColMap to demonstrate how headset recordings of youth navigating their Google Earth VR neighborhood can produce *lines of learning* indexed by video frames that track gaze, distance, attention and speed. ColMap data produces fluid lines that trace "flying" navigation not easily tracked. These lines clearly showcase differences in engagement between the analog and digital neighborhood,



and make it possible to compare across both. In addition, we added a tool to ColMap to search for frames that we could correlate with points line trajectories.

Specific to our data, we noted youths' attempts to "touch" and "hold" their digital neighborhood through repeated clicks and points via handheld controller. These limitations echo Puig de la Bellacasa's argument for digital environments that consider new methods for touch and haptic digital engagement (2019). ColMap lines indicated moments of moments of close attention through frame density, while lines of sparsely populated frames indicate liminal spaces of movement from one location to the next. In VR, youth movements defied the social, cultural and physical boundaries of the analog neighborhood. Through ColMap data, we could compare the ways youth thought about, moved through and attempted to "touch" digital representations that partially depicted their analog lives via the handheld controllers youth used to navigate. The lines that youth produced by traversing their digital neighborhoods visually depicted the stories of their lived experience and highlighted the areas that held their interest, gaze and interactions in ColMap. Liberated through the digital environment, youth shared their meaning with us while questioning the limitations of the model, and limitations of digital representation more broadly. ColMap enabled spatial interaction data to be linearly traced, annotated and analyzed along every altitude of Google Earth. Often their journeys became emotionally charged as they recognized areas of sentimental interest and questioned important discrepancies between their lived analog experiences and their digital encounters.

ColMap depicted youths' moment-to-moment changes in interest across time enabling us to see what in the analog environment "held" them. In addition, youth were able to begin to critically question the "truth" of digital representations and their personal experience. ColMap data provides a way to visually compare digital learning-along-lines with comparable analog trajectories, thus opening up opportunities for critical interrogation of digital representations. As the lines between analog reality and digital fantasy increasingly blur, we believe these insights provide educators and researchers with needed data to intentionally direct the future of learning.

References

Engeström, Y. (1987). Learning by expanding: *An activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultit.

Fisher, A., Cannizzaro, R., Cochrane, M., Nagahawatte, C., & Palmer, J. L. (2021). *ColMap: A memory-efficient occupancy grid mapping framework*. *Robotics and Autonomous Systems*, 142, 103755.

Knox, J. (2019). What does the 'postdigital' mean for education? Three critical perspectives on the digital, with implications for educational research and practice. *Postdigital Science and Education*, 357–370.

Marin, A., Taylor, K., Shapiro, B., & Hall, R. (2020). Why learning on the move: Intersecting research pathways for mobility, learning and teaching. *Cognition and Instruction*, 38(3), 265-280.

Puig de la Bellacasa, M. (2017). *Matters of Care: Speculative Ethics in More than Human Worlds* (Vol. 41). University of Minnesota Press.

Riesland, E. (2023). *Reimagining place-based education for our postdigital world*. Doctoral dissertation, [University of Washington]. ProQuest Dissertations & Theses Global.

Ross, J. (2023). *Digital futures for learning : speculative methods and pedagogies*. Routledge, Taylor & Francis Group.

Shapiro, B., Hall, R., & Owens, R. (2017). Developing & using interaction geography in a museum. *International Journal of Computer-Supported Collaborative Learning*, 12(4), 377-399.

Taylor, K. H., (2017). Learning along lines: Locative literacies for reading and writing the city. *Journal of the Learning Sciences*, 26(4), 533–574. <https://doi.org/10.1080/10508406.2017.1307198>

Vossoughi, S., & Gutiérrez, K. D. (2014). Studying movement, hybridity, and change: Toward a multi-sited sensibility for research on learning across contexts and borders. *Teachers College Record* (1970), 116(14), 603–632.

Acknowledgments

We would like to thank Sam Riesland for modifying ColMap for analytic purposes and making it available for download at <https://github.com/samr/colmap>.



Cultivating Resilience: A Participatory Approach to STEAM Curriculum in Community Gardens

Benedetta Piantella, NYU Tandon School of Engineering, benedetta.piantella@nyu.edu
Syeda Anjum, NYU Tandon School of Engineering, sna318@nyu.edu

Abstract: This demonstration introduces a brainstorming card deck co-created in conversation with environmental educators, community organizers, digital democracy advocates and other community experts. This card deck was designed to help collectively construct ideas for a resilience-forward and sustainability-focused curriculum to be hosted in community gardens, and other informal learning settings. The deck, reminiscent of Tarot, offers a dynamic opportunity for collaborative curriculum design, while fostering a sense of interconnectedness and addressing global challenges through the co-design of transformative place-based learning experiences.

Community gardens and resilience

Community gardens serve as vibrant sites of resilience and offer unique opportunities for hands-on ecological experiences. These green spaces represent a collective response to challenges such as food insecurity, environmental degradation, and social isolation. Through shared cultivation, community members not only nurture the land but also cultivate social bonds, fostering a sense of belonging and mutual support, contributing to the resilience of the community against external shocks. Additionally, community gardens often serve as educational hubs, especially during emergencies, imparting valuable knowledge about sustainable agriculture, biodiversity, and environmental stewardship. In the face of broader global crises, community gardens stand as living examples of how grassroots initiatives can strengthen the fabric of communities, offering a tangible and nurturing space where resilience takes root and flourishes (Chan, DuBois, Tidball, 2015).

Together with environmental educators, community organizers, digital democracy advocates and other experts, we have embarked on the co-design of a card deck for facilitating the brainstorming of ideas around a resilience-based curriculum for community gardens, and other green learning spaces. Our card deck and brainstorming activities draw inspiration from Dan Lockton's 'New Metaphors' card deck. Lockton's work has encouraged us to explore metaphorical avenues that resonate with diverse audiences, promoting a more inclusive and community-driven definition of resilience. While traditional card decks, such as 'Getting To Resilience' (Germraad, 2014), primarily focus on engineering perspectives and infrastructural resilience, our project takes a distinctive path by weaving together elements of play, environmental awareness, and kinship. This departure underscores our commitment to a holistic, ecosystem-driven approach to community resilience.

Card deck overview

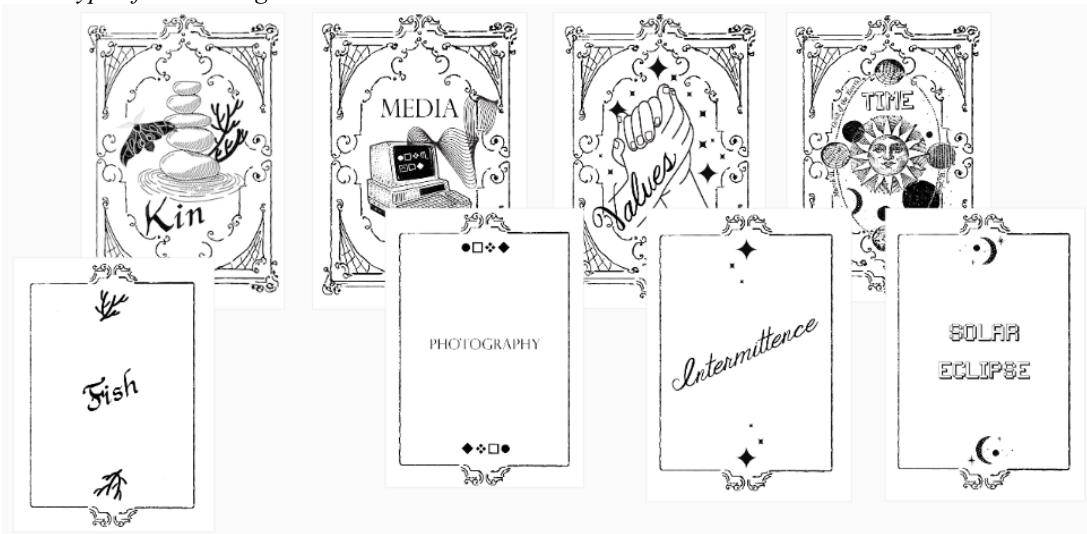
Our card deck (in Figure 1) draws inspiration from diverse sources, combining elements reminiscent of Tarot and other playing cards. The design encompasses six categories: *Kins*, *Media*, *Phenomena*, *Values*, *Time*, and *Themes*. Each category fulfills its purpose in guiding the ideation of place-based resilience and sustainability curriculum:

- *Kin* cards encourage participants to think about the interconnectedness of our world, and provide inspiration from various natural elements, fostering a deeper inquiry into our ecological relationships.
- *Media* cards prompt users to think outside of the box in connecting media creation with curriculum content and facilitate the incorporation of media production to enhance learning experiences.
- *Phenomena* cards encourage exploration of how natural events can be integrated into the learning process and spark creativity.
- *Values* cards guide the incorporation of ethical principles and sustainable values into the curriculum design, and help facilitate discussions on responsible practices in community learning environments.
- *Time* cards introduce a temporal element to the brainstorming activity allowing us to acknowledge the frequency, duration, intermittence and temporality of natural events.
- *Themes* cards present different overarching topics that were shared among the environmental educators, community organizers and experts, and can serve as a starting point.

This card deck is a tool to facilitate a series of group brainstorming sessions, designed to promote collective ideation and co-design of place-based educational activities (Gruenewald, 2003; Sobel, 2004) and encourage participants to delve into the interconnectedness of human and ecological systems. By guiding participants

through a scaffolded process of collaborative curriculum design, participants will be able to collectively construct their own pathway while reflecting on what criteria and metrics could capture the overall outcomes of the experiential learning activities, such as increased environmental awareness, enhanced community bonds, and the cultivation of sustainable practices. In addition to the predefined cards, the deck includes write-in cards, allowing participants to contribute and adapt the deck based on their unique site, insights and experiences to ensure the tool remains dynamic and responsive to the evolving needs of different learning communities.

Figure 1
Prototype of Cultivating Resilience Card Deck



Demonstration

During the 2024 ISLS Annual Meeting, our team proposes to conduct an engaging and interactive demonstration of multiple activities facilitated by the card deck. Attendees will have the opportunity to participate in a collaborative curriculum design activity, utilizing the cards to imagine resilience-focused and sustainability-oriented learning experiences. The demonstration also provides a platform for participants to engage in discussions surrounding the role STEAM education can play in fostering community resilience.

By integrating the card deck into community garden settings, we hope to support communities in addressing their local and global challenges through multidisciplinary activities that foster creativity, environmental consciousness, and a sense of interconnectedness. By centering resilience and sustainability, we hope to embody the spirit of this year's ISLS Annual Meeting, contributing actively to the broader conversation on communal healing and the role public pedagogy can play in supporting community wellbeing.

References

Chan, J., DuBois, B., & Tidball, K. G. (2015). Refuges of local resilience: Community gardens in post-Sandy New York City. *Urban Forestry and Urban Greening*, 14(3), 625–635.

Gruenewald D. A. (2003). Best of both worlds: A critical pedagogy of place. *Educational Researcher*, 32, 3-12.

Lockton, D., Singh, D., Sabnis, S., Chou, M., Foley, S., & Pantoja, A. (2019). New metaphors: A workshop method for generating ideas and reframing problems in design and beyond. In *Proceedings of the 2019 on Creativity and Cognition* (pp. 319-332).

Michael Germeraad. (2014). *The Resilience Deck*. Getting to Resilience.
<https://gettingtoresilience.wordpress.com/the-resilience-deck/>

Sobel D. (2004). *Place-based education: Connecting classroom and community*. Great Barrington, MA: The Orion Society.

Acknowledgments

We extend our gratitude to NYU and the *This Is Not A Drill* Fellowship for their support towards the development of this public pedagogy project around resilience-focused curriculum in community gardens.



BurnAR, ARScope, and Magic Arrow: Improving Interactive and Pedagogical Design in Augmented Reality-based Learning

Parastoo Alikhani, Pooya Sabeti

parastu.alikhani@gmail.com, pooyasabeti97@gmail.com

Shahid Beheshti University

Abstract: in most cases, interacting with virtual objects in AR experience just clicking on phone screen. This style of interaction can reduce the sense of presence in AR-based learning. Also, we have found that the literature of designing a learning environment based AR often focuses on enhance the virtual aspect design, while the reality aspect is neglected. As a result, designing interactions and pedagogical approaches is a crucial consideration. We aimed to create a more immersive and purposeful learning experience.

Problem statement

During the COVID-19 pandemic, science learning became a significant challenge for students, particularly in abstract concepts and conducting experiments. As a result, students were often limited to watching video as a third person. Aside from pandemic, many public schools in developing countries do not have access to high-quality materials and tools for conducting scientific experiments. Moreover, repeatedly reminding students of the dangers during performing unsafe experiments can diminish their excitement and enthusiasm for discovery. These issues were identified during semi-structured interviews with 16 science teachers. To overcome these difficulties, researchers have proposed using Augmented Reality (AR) to support science learning over the past decade. Virtual experiments allow students to obtain results more quickly with less setup time in the safe environment.

Generally, many studies have also demonstrated that AR can enhance the quality of learning experiences by creating a more interactive learning environment (Weng, Otanga, Christianto, & Chu, 2020), supporting the learning of abstract concepts (Wong, Ken, Tsang, & Chiu, 2021; Virata & Castro, 2019), and increasing the sense of presence (Chang et al. 2022). However, based on a decade of experience of the author in designing and implementing AR systems for learning environments, we have found that the literature of designing a learning environment based AR often focuses on enhance the virtual aspect design, while the reality aspect is neglected. Additionally, interacting with virtual elements on screen usually involves only clicking. However, this type of interaction can reduce the authenticity of AR experiences. Therefore, designing interactions and pedagogical approaches is crucial to enhance the authenticity of AR experiences.

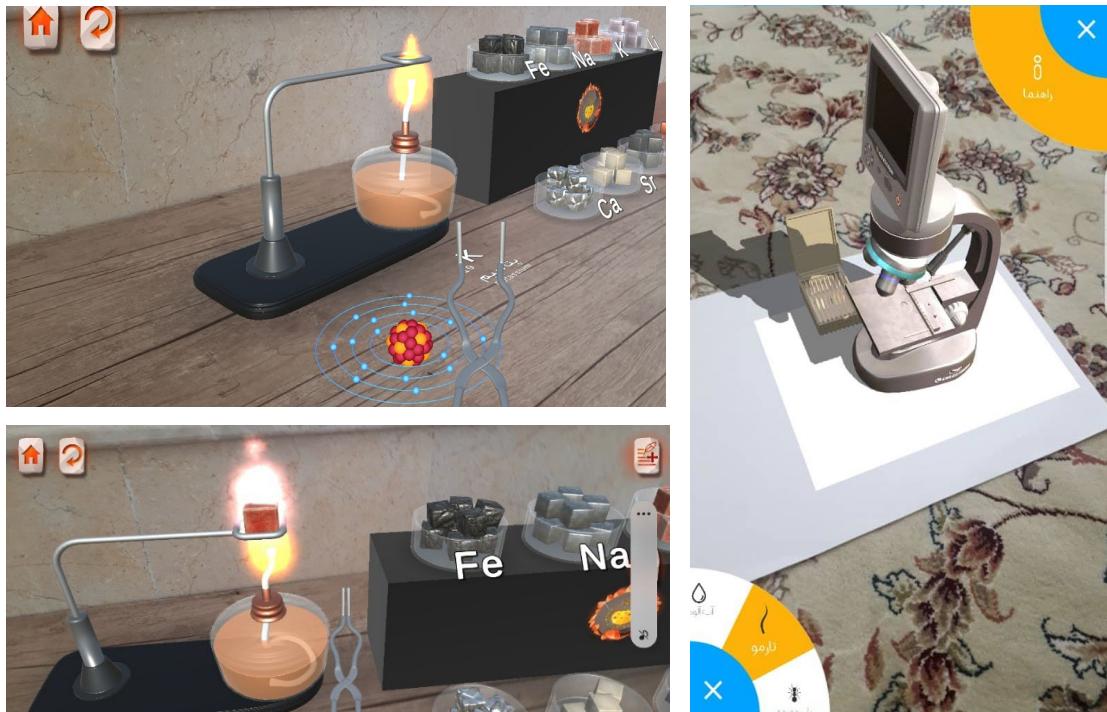
Our solution

Two AR applications, called “BurnAR” and “ARScope”, were developed by authors using the Unity engine (Fig.1). In the marker based ARScope app, students are responsible for all interactions with the microscope and virtual objects. Consequently, each student possesses a virtual microscope, which can be set up and used to examine the microstructure of various materials, such as hair or polluted water. In their dashboard, students have access to a note and video recorder option, enabling them to document their observations scientifically and share them with their peers.

BurnAR is a marker-less AR app that provides the possibility of chemical candles experiment with elements are less available. The design of user interactions with virtual objects was designed in a different way to give students a sense of presence. So that there is no need to click on the phone screen. It is enough for the user to imagine his/her phone as a laboratory clamp and, in the same way as in real world, take the elements and place them on the flame. The color of the flame changes based on the chemical element and the atomic structure of that element also appears. According to the Think-Pair-Share as a cooperative technique (Lyman, Tredway, & Purser, 2023), from the beginning, the system asks the student to press the record button and provide his verbal explanation on it at the same time. Then, share it with his/her peers. After receiving the peer feedback, he/she can do the experiment again.

In this way, the reality aspect of the AR experience is improved with learning approaches. In other words, the user purposefully goes back and forth between reality and virtual aspects. Donnelly (2006) emphasized the importance of integrating technology with learning techniques and theories from science and psychology to achieve satisfactory and meaningful learning outcomes. Similarly, Saltan and Arslan (2017) expressed concern about the lack of attention paid by developers of augmented reality-based educational software to instrumental learning strategies and theories.

Figure 1
The BurnAR (left) and ARScope (right)



Interaction design

In designing interactions, we focused on two modes of user-content and user-user interaction. To improve students' learning and motivation, we included the following innovation in the design:

- *Sense of presence*: creating a sense of presence by simulating the movements of laboratory instruments according to reality. For example, clamp movements are beyond clicking on the phone screen.

- *Learner control*: each student has control over the virtual objects and the learning experience. First-person interaction with virtual objects, multimedia recording of experiences, the possibility of receiving feedback from peers, and sharing are among the features that were included in the design to increase learner control. so students can feel that their success does not depend on external factors.

- *Active participation*: The reality aspect of AR-based learning was experienced more purposefully by including think-pair-share cooperative technique. In our previous works, we have also embedded learning approaches in the design of AR (Fig. 2). In "Magic Arrow" app, the user experience was designed according to the concept map approach. In this way, each student should identify the nutritional relationship between the animals in the picture with virtual arrows.

Figure 2
The Magic Arrow app



References

Chang, H. Y., Binali, T., Liang, J. C., Chiou, G. L., Cheng, K. H., Lee, S. W. Y., & Tsai, C. C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. *Computers & Education*, 191, 104641.

Chen, S. Y., & Liu, S. Y. (2020). Using augmented reality to experiment with elements in a chemistry course. *Computers in Human Behavior*, 111, 106418.

Donnelly, R. (2006). Integrating learning technologies with experiential learning in a postgraduate teacher education course. *Studying Teacher Education*, 2(1), 91-104.

Jiang, Q., Li, Y., & Shypenka, V. (2018). Loneliness, individualism, and smartphone addiction among international students in China. *Cyberpsychology, Behavior, and Social Networking*, 21(11), 711-718.

Lyman, F. T., Tredway, L., & Purser, M. (2023). 9 Think-Pair-Share and ThinkTrix. *Contemporary Global Perspectives on Cooperative Learning: Applications Across Educational Contexts*, 1992, 2016.

Saltan, F., & Arslan, K. (2017). A comparison of in-service and pre-service teachers' technological pedagogical content knowledge self-confidence. *Cogent Education*, 4(1), 1311501.

Virata, R. O., & Castro, J. D. L. (2019, January). Augmented reality in science classroom: Perceived effects in education, visualization and information processing. In *Proceedings of the 10th International Conference on E-Education, E-Business, E-Management and E-Learning* (pp. 85-92).

Wang, J. C., Hsieh, C. Y., & Kung, S. H. (2023). The impact of smartphone use on learning effectiveness: A case study of primary school students. *Education and Information Technologies*, 28(6), 6287-6320.

Weng, C., Otanga, S., Christianto, S. M., & Chu, R. J. C. (2020). Enhancing students' biology learning by using augmented reality as a learning supplement. *Journal of Educational Computing Research*, 58(4), 747-770.

Wong, C. H., Tsang, K. C., & Chiu, W. K. (2021). Using augmented reality as a powerful and innovative technology to increase enthusiasm and enhance student learning in higher education chemistry courses. *Journal of Chemical Education*, 98(11), 3476-3485.



The Synthesis Lab: Facilitating Sustained Knowledge Creation in Collaborative Discourse

Xinran Zhu, University of Pennsylvania, xrzh@upenn.edu

Hong Shui, University of Minnesota Twin Cities, shui0003@umn.edu

Ishan Joshi, University of Minnesota Twin Cities, joshi304@umn.edu

Wenxi Chen, University of Pennsylvania, chenwx@seas.upenn.edu

Bodong Chen, University of Pennsylvania, cbd@upenn.edu

Abstract: Knowledge synthesis is a critical process in computer-supported collaborative learning encompassing the analysis and integration of ideas fostered through interactions with peers in digital environments. This demo introduces the design of The Synthesis Lab, which aims to support students in synthesizing ideas from their online discussions in higher education classrooms to support the creation and advancement of student ideas. The tool offers structured workspaces for students to decompose the synthesis process into intermediate synthesis products and features two key iterative processes of knowledge synthesis in collaborative settings: categorizing peers' ideas into conceptual building blocks and developing a synthesis of the discussions. Future implementation and evaluation of the design will contribute to both research and practice.

Introduction

Collaborative discourse refers to the ways in which learners interact, communicate, and build knowledge together in a learning environment. It is a common practice in classrooms to facilitate students' engagement with course materials. For example, in higher education classrooms, students often participate in discourse to collaboratively make sense of course readings, which have been shown to enrich learning experiences in various ways (Chen, 2019; Nguyen & Henderson, 2020; Richardson & Ice, 2010). In the context of computer-supported collaborative learning (CSCL), one key goal of discourse is to support students in sustained knowledge creation through creating and advancing student-generated artifacts (e.g., posts on online discussion forums) (Paavola & Hakkarainen, 2021). In digital spaces, these artifacts reflect the transformation of students' intangible ideas into explicit digital entities that can be further articulated, shared, connected, and extended in long-term processes (Hakkarainen, 2009). Such processes require students' deep engagement with artifacts, which can be challenging without effective scaffolds. For example, teachers have raised concerns about the quality of students' contributions to the discourse, which often fail to go beyond simply knowledge sharing to demonstrate critical thinking, interrogate claims, take intellectual risks, synthesize knowledge, or transfer knowledge to a new domain (Egger, 2022; Keller, 2013). Students tend to focus on simply summarizing learning resources and exchanging their interpretations, rather than engaging in the generation of creative ideas, building upon their peers' thoughts, or fostering new knowledge creation. Furthermore, even when students do generate thoughtful ideas, they often don't evolve into novel knowledge due to a lack of avenues for continual refinement.

To tackle these challenges, there's an emerging need to scaffold students in connecting, analyzing, and advancing their artifacts for productive collaborative discourse activities. This scaffolding is crucial for enabling students to effectively synthesize their ideas into coherent and innovative insights. In other words, for productive collaborative discourse, the importance of synthesis-making becomes evident. *Knowledge synthesis* is one important form of cognition in human learning and collaboration. In contrast to other cognitive processes such as interpreting and evaluating new information, synthesis-making involves rising above current levels of explanation which results in understanding phenomena on a higher plane and the creation of new concepts (van Aalst, 2009; Scardamalia & Bereiter, 2014). It involves skillfully and strategically weaving together diverse strands of information to foster conceptual innovation, generate novel knowledge, and design creative solutions (Deshryver, 2014; Morabito & Chan, 2021; Nonaka & Takeuchi, 2007; Qian et al., 2020).

Research from various disciplines has examined processes or concepts related to knowledge synthesis. In information sciences, scholarly synthesis has been studied to understand how researchers individually and cooperatively synthesize literature or concepts for scientific inquiry (Morabito & Chan, 2021; Qian et al., 2020). Scholars in this field highlighted important processes of knowledge synthesis such as capturing context information and information reuse (Ackerman & Halverson, 2004; Morabito & Chan, 2021). The concept of knowledge synthesis has also been explored in the context of educational practices, sometimes under different terms or implicitly. Linn (2006) developed the Knowledge Integration framework dedicated to guiding learners from a fragmented comprehension of concepts to a more cohesive and integrated understanding of scientific



phenomena. Later, DeSchryver (2014) developed a framework for web-mediated knowledge synthesis which includes six strategies for individuals such as divergent keyword search, in-the-moment insights, repurposing, and note-taking. Moreover, the knowledge building model emphasizes the notion of “rise above” to synthesize and build on previous ideas which leads to the development of novel knowledge (Scardamalia & Bereiter, 2014).

These studies highlighted various facets of knowledge synthesis, such as processing and managing information, connecting and building upon diverse ideas, summarizing and organizing perspectives, and constructing a cohesive understanding of particular phenomena. They all demonstrated the crucial role of knowledge synthesis in either individual or collaborative learning scenarios. However, there is a lack of theoretical understanding and empirical investigation on how learning, particularly in collaborative settings, is mediated through knowledge synthesis. A question arises: How does knowledge synthesis facilitate interaction and ongoing knowledge creation? Additionally, there is a lack of explicit support for the knowledge synthesis process within a collaborative learning context. These gaps present an opportunity for further research that recognizes knowledge synthesis as an integral process in collaborative learning. It also highlights the need to develop learning designs that provide explicit support systems to integrate knowledge synthesis in collaborative learning contexts.

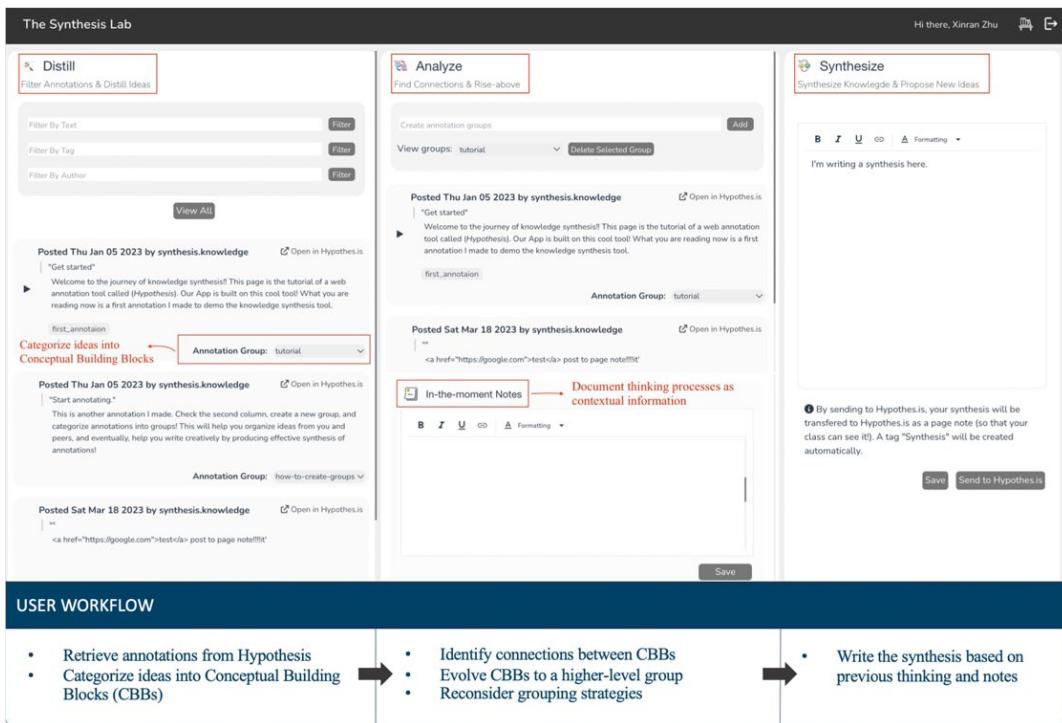
To fill these gaps, we designed *The Synthesis Lab* to facilitate the knowledge synthesis processes to deepen collaborative discourse. Particularly, The Synthesis Lab helps students deconstruct the complex synthesis-making process into smaller building blocks and guides students through the key steps, such as distilling, connecting, analyzing, and rising above ideas generated from the collaborative discourse. These steps guide students to discover the interrelationship between peers’ posts other than the simply reply relationships, which leads to further rising above previous ideas and constructing coherent knowledge out of fragmentary information.

The design is situated in the context of social annotation, leveraging web annotation tools to facilitate student discourse. *Web annotation* is a genre of information technology that provides a unique way for people to interact with digital content. It allows a user to annotate information in a shared web document and thereby anchors further discussion to the annotated information (W3C Web Annotation Working Group, 2016). *Social annotation* refers to the application of web annotation tools in educational settings to support student interaction around course materials and with each other. In higher education, social annotation has been widely adopted as an online discussion activity where students collaboratively read and annotate course readings (Sun et al., 2023; Zhu et al., 2020). Particularly, students annotate the shared reading documents and reply to each other’s annotations. The Synthesis Lab is designed to facilitate students’ knowledge synthesis of the class annotations. Supported by sophisticated pedagogical designs, the synthesized knowledge can be connected with other learning events to support sustained knowledge creation.

The Synthesis Lab

The Synthesis Lab (see Figure 1 for the interface and example user workflow) retrieves students’ discourse data on a web annotation platform – Hypothesis. The workflow within the tool revolves around two primary goals: categorizing peers’ ideas into conceptual building blocks (CBBs) (Morabito & Chan, 2021) and developing a synthesis of the student annotations. These goals are achieved through interaction across three vertically organized workspaces: Distill, Analyze, and Synthesize. This organization provides structured workspaces for students to decompose the tasks into intermediate synthesis products: insource annotations, per-source summaries, and cross-source syntheses (Qian et al., 2020). The design encourages students to fluidly navigate between these workspaces, allowing them to revisit annotations and thoughts iteratively, recognizing that the synthesis-making process is non-linear in nature.

Figure 1
Interface and User Workflow of The Synthesis Lab



The Synthesis Lab

Distill
Filter Annotations & Distill Ideas

Filter By Text Filter By Tag Filter By Author

Analyze
Find Connections & Rise-above

Create annotation groups Delete Selected Group

Posted Thu Jan 05 2023 by synthesis.knowledge
"Get started"
Welcome to the journey of knowledge synthesis! This page is the tutorial of a web annotation tool called (Hypothesis). Our App is built on this cool tool! What you are reading now is a first annotation I made to demo the knowledge synthesis tool.

first_annotation

Posted Sat Mar 18 2023 by synthesis.knowledge
"Start annotation"
This is another annotation I made. Check the second column, create a new group, and categorize annotations into group! This will help you organize ideas from you and peers, and eventually, help you write creatively by producing effective synthesis of annotations!

Annotation Group: how-to-create-groups

Posted Sat Mar 18 2023 by synthesis.knowledge
<https://google.com> post to page note!!!

Synthesize
Synthesize Knowledge & Propose New Ideas

I'm writing a synthesis here.

By sending to Hypothes.is, your synthesis will be transferred to Hypothes.is as a page note (so that your class can see it). A tag "Synthesis" will be created automatically.

USER WORKFLOW

- Retrieve annotations from Hypothesis
- Categorize ideas into Conceptual Building Blocks (CBBs)

→

- Identify connections between CBBs
- Evolve CBBs to a higher-level group
- Reconsider grouping strategies

→

- Write the synthesis based on previous thinking and notes

Categorizing peers' ideas into CBBs

Once a student has selected the reading for analysis, the tool retrieves associated class annotations via Hypothesis's API. In the Distill column, students are able to filter annotations by keywords, authors, and tags. Meanwhile, students start to analyze annotations by creating Annotation Groups in the Analyze column, where they categorize annotations into different categories following various strategies. For instance, some students may opt to group annotations by "applications" or "methodology", while others may group them based on semantic meanings. This step allows students to organize ideas into CBBs, which become the metadata and contextual information for future synthesis work (Morabito & Chan, 2021). Additionally, students jot down their thoughts in the "In-the-moment Notes" box to document the contextual information surrounding their decisions. This step encourages active analysis of peers' ideas and the meaningful integration of concepts.

Developing a synthesis of the discourse

Following their analysis of individual annotations, this step prompts students to shift their attention to the Annotation Groups in order to identify connections or reconsider their grouping strategies. For example, they can merge two groups as a new group (combining CBBs to a higher level CBB) or transfer annotations from one group to another. This process encourages students to repurpose and reinforce their learning by ruminating over the categories and revisiting the annotations/notes (Deschryver, 2014). Ultimately, students start the synthesis writing phase in the Synthesize column, drawing upon all their existing notes and activities to compose a comprehensive synthesis.

Implications

The Synthesis Lab has been implemented in several classrooms to support collaborative discourse in the context of social annotation. The implementations often involve sophisticated pedagogical strategies, collaboratively developed by researchers and instructors. For instance, in a graduate-level course, students were tasked with synthesizing key ideas from their annotations. This synthesized knowledge was then used to facilitate their in-class discussion and the completion of group projects. In this study, social annotation activities extend beyond just the use of the Hypothesis platform, incorporating additional learning events to synthesize annotations and connect this synthesized knowledge with other learning events.

In addition to practical implications, ongoing research on the investigation of the design enactments aims to contribute to the CSCL literature by extending our understanding of the role of knowledge synthesis in collaborative learning.



Presentation

The presentation will include a combination of a demo and discussion of related research projects.

References

Ackerman, M. S., & Halverson, C. (2004). Organizational memory as objects, processes, and trajectories: An examination of organizational memory in use. *Computer Supported Cooperative Work (CSCW)*, 13(2), 155–189.

Chen, B. (2019). Designing for networked collaborative discourse: An UnLMS approach. *TechTrends*, 63(2), 194–201.

Deschryver, M. (2014). Higher Order Thinking in an Online World: Toward a Theory of Web-Mediated Knowledge Synthesis. *Teachers College Record*, 116(12), 1–44.

Egger, M. L. (2022). *Reading with social, digital annotation: Encouraging engaged critical reading in a challenging age*. Doctoral dissertation. Old Dominion University.

Hakkarainen, K. (2009). A knowledge-practice perspective on technology-mediated learning. *International Journal of Computer-Supported Collaborative Learning*, 4(2), 213–231.

Keller, D. (2013). *Chasing literacy: Reading and writing in an age of acceleration*. University Press of Colorado.

Linn, M. C. (2006). The Knowledge Integration Perspective on Learning and Instruction. In *The Cambridge handbook of: The learning sciences* (pp. 243–264). Cambridge University Press.

Morabito, J. S., & Chan, J. (2021, June). Managing Context during Scholarly Knowledge Synthesis: Process Patterns and System Mechanics. In *Proceedings of the 13th Conference on Creativity and Cognition (Virtual Event, Italy) (C&C '21)* (pp. 1-5).

Nonaka, I., & Takeuchi, H. (2007). The knowledge-creating company. *Harvard business review*, 85(7/8), 162.

Nguyen, H. T. T., & Henderson, A. (2020). Can the reading load be engaging? Connecting the instrumental, critical and aesthetic in academic reading for student learning. *Journal of University Teaching & Learning Practice*, 17(2). <https://doi:10.53761/1.17.2.6>

Paavola, S., & Hakkarainen, K. (2021). Trialogical Learning and Object-Oriented Collaboration. In U. Cress, C. Rosé, A. F. Wise, & J. Oshima (Eds.), *International Handbook of Computer-Supported Collaborative Learning* (pp. 241–259).

Qian, X., Fenlon, K., Lutters, W., & Chan, J. (2020). Opening up the black box of scholarly synthesis: Intermediate products, processes, and tools. *Proceedings of the Association for Information Science and Technology*, 57(1), e270.

Richardson, J. C., & Ice, P. (2010). Investigating students' level of critical thinking across instructional strategies in online discussions. *The Internet and Higher Education*, 13(1), 52–59.

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 397-417). Cambridge University Press.

Sun, C., Hwang, G. J., Yin, Z., Wang, Z., & Wang, Z. (2023). Trends and issues of social annotation in education: A systematic review from 2000 to 2020. *Journal of Computer Assisted Learning*, 39(2), 329-350.

van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *International Journal of Computer-Supported Collaborative Learning*, 4(3), 259–287.

W3C Web Annotation Working Group. (2016). available at: www.w3.org/annotation/

Zhu, X., Chen, B., Avadhanam, R. M., Shui, H., & Zhang, R. Z. (2020). Reading and connecting: Using social annotation in online classes. *Information and Learning Sciences*, 121(5/6), 261–271.



LS Explorer: An AI Tool for Navigating Learning Sciences Research using Retrieval-Augmented Generation (RAG)

Yipu Zheng, Paulo Blikstein

yipu.zheng@tc.columbia.edu, paulob@tc.columbia.edu

Teachers College, Columbia University

Abstract: Built upon our previous research on analyzing the full corpus of papers in the proceedings of the International Conference of Learning Sciences (ICLS) and the International Conference on Computer-Supported Collaborative Learning (CSCL), this work presents a large language model (LLM)-based tool to help researchers navigate scholarship in the learning sciences more effectively. Retrieval-Augmented Generation (RAG) is employed to increase the trustworthiness of outputs and address the issue of hallucination of the LLMs. The contribution of this work is two-fold: First, it presents a tool that could be beneficial for members of the Learning Sciences community. Second, it provides opportunities to test out new ways of collaboration between researchers and AI that might not be able to be captured without such an interface.

Overview

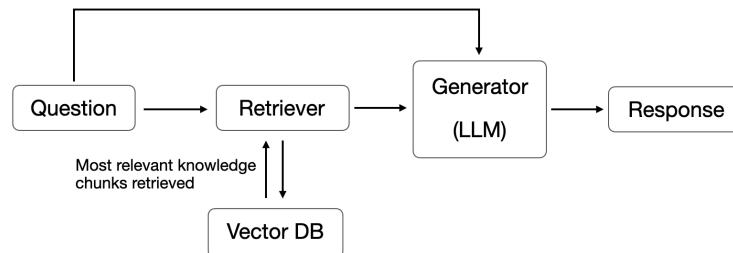
In our previous work (Zheng et al., 2023), we have looked at conference papers published in the proceedings of the International Conference of Learning Sciences (ICLS) and the International Conference on Computer-Supported Collaborative Learning (CSCL) from 1995 to 2020 to explore the changes of research foci and collaboration dynamics in the two research communities over the past 25 years. During our analysis, we interacted with thousands of research papers and realized how much valuable knowledge we have developed within our communities. At the same time, we also realized how difficult it is for a researcher, especially a new scholar in the field, to navigate through all these papers and allocate relevant works. Recent developments in machine learning, led by large transformer models, have brought new possibilities for humans to interact with information and knowledge (Gao et al., 2023). Thus, we decided to develop the first LLM-powered tool specifically for the Learning Sciences community to identify and explore relevant learning theories and research more effectively, using 5092 papers contributed by 2975 authors from the proceedings of ICLS and CSCL from 1995 to 2022.

This pilot version of the tool is built using GPT-4 and the Retrieval Augmented Generation (RAG) approach (Lewis et al., 2020). Retrieval-Augmented Generation (RAG) combines the capabilities of a large language model with an external information retrieval system to enhance the performance of language models, especially in tasks requiring access to a broad range of factual information (Ji et al., 2023). To employ RAG, we first created an external vector database to index conference papers in the proceedings of ICLS and CSCL in given years. All content of the conference papers was parsed and segmented. We then created embeddings for these segments using OpenAI's text-embedding-ada-002 model and stored the results in a Pinecone vector database. As shown in Figure 1, the language model generates text, while the information retrieval system fetches relevant external information. When given an inquiry, the RAG system, built with the LangChain framework, first uses its retrieval component to search for and gather relevant documents from the external vector database that contains ICLS and CSCL papers. Next, the retrieved information is combined with the original input query and serves as the new input for the language generation model (GPT-4 is the model used in this pilot version of the tool). In addition, we used OpenAI's Chat Completion API to simulate the conversation with users.

Using this method, our tool can answer highly specific questions that require up-to-date information in the learning sciences research. Also, our tool provides citations to all relevant documents from the external vector database to enable fact-checking and try to avoid "hallucination" (Zhang et al., 2023).

Figure 1

Flow Diagram Illustrating How Retrieval Augmented Generation (RAG) Works in LS Explorer



Design features

In this pilot version of the LS Explorer tool, we mainly focus on two functionalities. The first function helps users synthesize information about specific topics in Learning Sciences based on past ICLS and CSCL conference papers. All information sources are provided in APA citation format to ensure the accuracy of the output. Users can also use the citation list as a tool to find relevant literature on specific topics. Figures 2(a) and 2(b) show screenshots of an example conversation. Some example questions or prompts could be:

- What is the definition of metacognition?
- What are some metacognitive scaffolds for classrooms?
- How do you encourage scientific inquiry?
- What are some design guidelines for introducing computational thinking in middle school classrooms?

The second functionality is called “chat with one paper”. This feature evolved during our user testing. Several participants suggested that it often took them a long time to skim through many papers and decide which ones were relevant. Thus this interface is designed to help users quickly identify a list of papers that contain certain keywords/ topics or written by certain authors in the ISLS database. As shown in Figures 2(c) and 2(d), users can select the paper from the list to learn more about a particular paper. The paper's content will then be loaded into the system, and users can learn more about the content by asking questions about the paper and receiving fact-based answers. If users find the information relevant, then they can easily allocate the pdf of the specific paper via the URL provided in the citation section and read the full paper.

Some example questions or prompts could be:

- Summarize the method used in this study.
- Summarize the study participants. What is their age group and demographic background?
- What are the findings?

Figure 2

Screenshots of the LS Explorer Tool Showcasing the “Synthesize LS Research” Interface and the “Chat with One Paper” Interface



LS Explorer

Synthesize LS Research

How can I assist you?

What are some metacognitive scaffolds that can be used in class?

Some metacognitive scaffolds that can be used in class include providing more explanations or visualizations as scaffolding in the activity that fade as students become more familiar with the environment. Other methods include making aspects of metacognition more explicit, prompting reflection, and making students' thinking visible. Adaptive scaffolding from human tutors, peers, and teachers can also support students' metacognitive monitoring and understanding. Additionally, the use of diagrams in computer-based training environments can scaffold cognitive and metacognitive processes, especially in low verbal ability learners.

- Citation: Xia, Y., Lee, H., & Borge, M. (2019). Exploring Students' Self-assessment on Collaborative Process, Calibration, and Metacognition in an Online Discussion. In Lund, K., Niccolai, G. P., Lavoué, E., Hmelo-Silver, C., Gweon, G., & Baker, M. (Eds.), *A Wide Lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings*, 13th International Conference on Computer Supported Collaborative Learning

Ask anything about learning sciences research! >

(a)

(b)

(CSCL) 2019, Volume 2 (pp. 945-946). Lyon, France: International Society of the Learning Sciences. Source: <https://repository.isls.org//handle/1/1742>

- Citation: Corliss, S. & Spitulnik, M. (2008). Student and Teacher Regulation of Learning in Technology-enhanced Science Instruction. In Kanselaar, G., Jonker, V., Kirschner, P. A., & Prins, F. J. (Eds.), *International Perspectives in the Learning Sciences: Creating a learning world. Proceedings of the Eighth International Conference for the Learning Sciences – ICLS 2008*, Volume 1 (pp. 167-174). Utrecht, The Netherlands: International Society of the Learning Sciences. Source: <https://repository.isls.org//handle/1/3091>
- Citation: Antonietti, A., Diller, K., Herman, P., Schnotz, W., Moreno, R., Marley, S., Helak, J., Fiore, S., Cuevas, H. M., & Scielzo, S. (2008). Metacognition in understanding multimedia presentations. In Kanselaar, G., Jonker, V., Kirschner, P. A., & Prins, F. J. (Eds.), *International Perspectives in the Learning Sciences: Creating a learning world. Proceedings of the Eighth International Conference for the Learning Sciences – ICLS 2008*, Volumes 3 (pp. 166-173). Utrecht, The Netherlands: International Society of the Learning Sciences. Source: <https://repository.isls.org//handle/1/3240>

Export Chat History

Ask anything about learning sciences research! >

LS Explorer

Chat with One Paper

This tab helps you quickly identify a comprehensive list of papers that contain certain keywords/ topics or written by certain authors in the ISLS database. To learn more about a particular paper, you can select the paper from the list and ask for a summary for any specific section of the paper.

Input a title, a topic or a researcher's name (please format the name as "last name, first name") to start:

creativity

Papers related to your input:

- Robot Diaries: Encouraging and Enabling Technological Creativity
- Robot Diaries: Encouraging and Enabling Technological Creativity
- Effects of social metacognition on micro-creativity: Statistical discourse analyses of group problem...
- Unpacking the Mediation of Invented Representations
- Creativity, Collaboration and Competence: Agency in Online Synchronous Chat Environment
- Fostering Creativity through Cross-Disciplinary Collaboration in an Online Dance Course
- Perspectives and Problem Solving in an Algebra Classroom
- Personalized Identity, Mentoring and Mathematical Conversation: The Math Forum's Online Mento...
- Building Creativity, Collaboration, Learning, and Creativity in a Virtual Gaming Environment

(c)

LS Explorer

Chat with One Paper

This tab helps you quickly identify a comprehensive list of papers that contain certain keywords/ topics or written by certain authors in the ISLS database. To learn more about a particular paper, you can select the paper from the list and ask for a summary for any specific section of the paper.

Input a title, a topic or a researcher's name (please format the name as "last name, first name") to start:

creativity

Papers related to your input:

- Effects of social metacognition on micro-creativity: Statistical discourse analyses of group problem...

What do you want to know about this paper?

Tips: Prompts like "summarize the method section" or "summarize the findings" are good places to start.

Summarize the participants in this study. What's their age group and demographic background?

Answer:

The participants in this study were 80 students in an urban US high school who attended four ninth grade algebra classes. Their age group would typically be around 14-15 years old. The demographic background of the participants included 40 girls and 40 boys, with racial distribution of 12 Asian, 27 Black, 28 Hispanic, and 13 White students.

Citation: Chiu, M. M. (2008). Effects of social metacognition on micro-creativity: Statistical discourse analyses of group problem solving. In Kanselaar, G., Jonker, V., Kirschner, P. A., & Prins, F. J. (Eds.), *International Perspectives in the Learning Sciences: Creating a learning world. Proceedings of the Eighth International Conference for the Learning Sciences – ICLS 2008*, Volume 1 (pp. 144-152). Utrecht, The Netherlands: International Society of the Learning Sciences.

URL: <https://repository.isls.org//handle/1/3088>

Export Chat History

Plan for the interactive demo session

For the 20-30 minutes of the interactive demo session, we plan to spend the first 5-10 minutes giving a brief introduction about the functionality of our tool and how we built it. We hope such an overview can help other members of the research community not only know more about our tool but also learn more about the recent developments in large language models and retrieval-augmented generation. Learning resources that we found helpful will be included during the overview as well.

After that, we will give audiences 10 minutes to try the LS Explorer tool on their own. Audiences can go to this website (<https://ls-explorer.streamlit.app/>) to try the tool on their own digital devices (e.g. laptops and smartphones) or use the laptops we set up on-site. In the last 5-10 minutes, we will hold a Q&A session where audiences are encouraged to ask questions about the tool or share their feedback and future design suggestions. At the same time, to make sure we can hear from as many people as possible, we will distribute pencils and post-it notes to all attendees to ask everyone to share their feedback/ ideas/ comments via written format.



Implications and applications of the tool

In this work, we present a novel tool specifically designed to assist researchers, particularly newcomers, in navigating the extensive corpus of academic papers published in the International Conference of Learning Sciences (ICLS) and the International Conference on Computer-Supported Collaborative Learning (CSCL). The development of this tool is an exploratory attempt crucial for enhancing scholarly work, as it allows researchers to easily locate, reference, and read relevant studies, thereby fostering more informed scholarly endeavors. As we continue to refine and expand the capabilities of the LS Explorer tool, we are looking for feedback and future collaborators. Through this interactive demo session, we also hope to solicit discussion on the potential and challenges of designing AI tools to transform how knowledge is accessed, understood, and utilized in our research community. In particular, we want to get feedback to inform our ongoing work on ensuring that the data is minimally biased towards topics or authors already with many publications, making sure that new scholars and topics are also prominent in the results.

References

Gao, Y., Xiong, Y., Gao, X., Jia, K., Pan, J., Bi, Y., ... & Wang, H. (2023). Retrieval-augmented Generation for Large Language Models: A survey. *arXiv preprint arXiv:2312.10997*.

Ji, Z., Lee, N., Frieske, R., Yu, T., Su, D., Xu, Y., ... & Fung, P. (2023). Survey of hallucination in natural language generation. *ACM Computing Surveys*, 55(12), 1-3

Lewis, P., Perez, E., Piktus, A., Petroni, F., Karpukhin, V., Goyal, N., ... & Kiela, D. (2020). Retrieval-augmented Generation for Knowledge-intensive NLP Tasks. *Advances in Neural Information Processing Systems*, 33, 9459-9474.

Zhang, Y., Li, Y., Cui, L., Cai, D., Liu, L., Fu, T., ... & Shi, S. (2023). Siren's Song in the AI Ocean: A Survey on Hallucination in Large Language Models. *arXiv preprint arXiv:2309.01219*.

Zheng, Y., Zhou, Z., Chen, J., & Blikstein, P. (2023). Outside-in, Inside-out, or Outside-out? Exploring the Flow of New Ideas and the Development of CSCL and ICLS via Co-Authorship Networks from 1995 to 2020. In *Proceedings of the 2023 International Conference on Computer-Supported Collaborative Learning (CSCL)*.

Acknowledgments

We thank Joel Wiebe and Abubukker Chaudhary at the University of Toronto for helping us to gain access to all papers used in this pilot project. We thank Xi Zhao, Xiaoying Lin, and Yimin Chen at Columbia University for their contribution as research assistants in the development and execution of this pilot project.



“The Isles of Ilkmaar”: A Data-rich, Multiplayer Virtual World for Teaching Data Science to Middle School Learners

Lisa Hardy, Sarah Radke, lhardy@concord.org, sradke@concord.org
The Concord Consortium

Jennifer Kahn, University of Miami, jkahnthorne@miami.edu

Abstract: This interactive session will demo a multiplayer virtual world designed to support inclusive, identity-aligned data science learning experiences for middle school girls and gender expansive youth. Participants will playtest the latest build of the game and explore datasets generated through gameplay. We will also solicit critical and constructive feedback from session participants regarding particular game design features. This session will demonstrate the potential of multiplayer gameplay for inclusive and youth-centered data science education, showcasing game features co-designed with youth to align with their identities, purposes, and interests.

Introduction

Providing opportunities in adolescence for identity-aligned participation in data work supports interest and engagement with data-rich fields, critical for addressing lack of diversity in these areas (Denner, 2011; Philip et al., 2013). Roleplaying game environments where data practices emerge from narratively grounded social interactions hold strong potential to broaden data science appeal and accessibility (Herman et al., 2020). Our design approach leverages multiplayer gameplay mechanics for authentic forms of collaborative data work called for in theories of data science as distributed social practice (D’Ignazio & Klein, 2020; Wilkerson & Polman, 2019). Our project aims to leverage the engaging, distributed nature of multiplayer games to situate data skills within narrative environments and social interactions meaningful to underrepresented youth.

This interactive demo will showcase “The Isles of Ilkmaar,” a multiplayer virtual world designed to support inclusive, identity-aligned data science learning experiences particularly for middle school-aged girls and gender expansive youth. Teams of players together inhabit a mystical island chain, on which mysterious events disrupt the harmony between its human and creature inhabitants. Players must work together to rebuild community across the creature factions, and restore balance to the island’s delicate ecology. Open world gameplay mechanics allow players to impact the shared world through actions like foraging for resources, crafting gifts and health potions, interacting with and befriending creatures, and tending to the island ecosystem. These open-ended activities generate personalized gameplay data logs, while accessible in-game data tools allow individual and collaborative data exploration to uncover insights about the game world and inform gameplay strategies.

In this interactive session, participants will be invited to join a game server to play the latest build of the Isles of Ilkmaar game world. Participants will have the opportunity to playtest gameplay activities, generate gameplay data, and use in-game data analysis tools to explore data and visualize patterns. The session will also highlight multiplayer capabilities and designed collaborative activities, allowing participants to play simultaneously and coordinate gameplay toward shared goals in a group “mini-quests.” Participants can access and explore pre-built gameplay datasets in the educational data analysis environment CODAP (Finzer & Damelin, 2016). We hope this first-hand experience of the virtual world and its integrated data features will showcase the learning potential at this intersection of multiplayer gameplay, purposeful data work, and inclusive learning environments.

Our project will also utilize this interactive tech demo session as a design review meeting. That is, we request that participants leverage their perspectives, interests, and expertise to consider and reflect on several game design features for relational, identity-aligned data science teaching and learning, as described in more detail below. Constructive feedback from this session will inform a critical reflection on our game design and the development of learning progressions (through mini-quests) that can be implemented in informal, game-based data science clubs (“Guilds”) with middle school students in the coming year. This session supports both virtual and in person participation, but in person participants will need to bring their own computers.

“The Isles of Ilkmaar” game design and key features

The Isles of Ilkmaar was designed in a collaboration of learning scientists, game designers and developers, and youth in the game’s target demographic. The game world was designed based on theoretical perspectives from the learning sciences that frame data science as a social, purpose-driven practice, and situated within a community of data users (Philip et al, 2013; Wilkerson & Polman, 2019). The design goal was to create a “data-rich” world

where youth engage with data as part of participation in an online data community. The game would be multiplayer, played in “Guilds,” or teams of players who inhabit the same game world instance and share a Discord server for out-of-game communication. Specific design goals and guiding principles were grounded in these perspectives, and informed the development of the game’s narrative, mechanics, world systems, and data tools. These guiding principles were to: 1) Support consequential, relational work with data through game narrative and mechanics tied to collective goals and visible impacts on the shared world. 2) Enable personalized purpose pathways for data, by positioning gameplay data as a flexible resource for players’ emergent in-game goals across multiple contexts and activities. 3) Scaffold a progression from personal data records toward larger social data sets through data sharing and aggregation across players.

Game narrative

The Isles of Ilkmaar comprise four distinct islands named Growth, Stability, Shadow, and Light, each home to native plant and creature species that together exist in a harmonious ecological balance (Figure 1a). At the start of the game, the islands experience a *Disruption* event leading to the isolation of creature communities, and mysterious illnesses affecting the creatures. Players are tasked with restoring the health of the creature populations and island ecosystem, and ultimately rebuilding the island community.

Figure 1

a) Game Map of Ilkmaar’s Four Island Ecosystem. b) The Player Avatar Creator



Game mechanics

To play the game, players create and customize their own avatar (Figure 1b), explore the islands, and interact with creatures by giving them gifts, foods, or health potions crafted from combinations of resources foraged across the islands. Each creature faction has different behaviors, preferences and needs. Gifts, foods or potions have different effects on the creatures’ mood, health or social stats, depending on the creature’s faction, color, or other attributes (Figure 2a). Players tend to the island environment using specialty potions that shift the balance of island energies (Figure 2b).

Figure 2

a) A Player and Rock Golems on Stability Island. b) Plot Energies Bar Graphs (with annotations)



World system

The world system specifies the underlying logic, relationships, and patterns that govern the dynamics of the world state and how player actions impact the game world. The Ilkmaar world system is highly connected and



interdependent. The game world has seasonal, weather, and day/night cycles that affect creature behaviors and resource availability. The health of the creature populations is tied to the health of the islands, while both systems are directly impacted by player foraging, crafting and gifting, and relationships with creatures.

Data tools

Player interactions with the game world all generate data. Each interaction with creatures or with the island ecosystem creates a data point as “a record of one repetition of a repeatable observational process” (Konold et al., 2017, p. 191). Data from player actions are automatically logged in their Data Diary, while additional sources of data are accessed at special locations around the islands. Players can view, explore and seek patterns in data using the Data Explorer, an intuitive interface based on the Concord Consortium’s popular data science platform for middle schoolers (Finzer & Damelin, 2016).

Summary of key Design features to support in-game data science

The *game narrative* situates players as agents in an interdependent fantasy ecosystem, and frames data as a useful resource for personal or social goals. Open-world *gameplay mechanics* allow players to impact the state of the shared world through activities like foraging for natural resources, or crafting gifts to befriend creatures. An interconnected **world system** models underlying relationships between player activities, the health and happiness of the creature populations, and the health and balance of the island biomes. In-game **data tools** log data generated by player actions and decisions to create personalized gameplay datasets that can be explored, visualized, shared and aggregated to inform gameplay strategy and community decisions.

Co-design with youth to support identity-aligned, data-rich gameplay

We engaged in game co-design with over 150 diverse youth participants aged 10-14 to inform inclusive game design focused on identity expression and meaningful data work. Methods included online surveys to gather preferences on specific game elements, as well as semi-structured interviews and focus group gameplay sessions using a storytelling design methodology. This participatory approach aimed to empower youth as co-designers and position the game narrative, mechanics, and data features as flexible resources for their emergent, collaborative goals grounded in the gameplay.

Surveys. Two online surveys were administered, featuring both multiple-choice and open-ended questions aimed to gather youth game preferences and elicit feedback on specific game design elements. Over 150 diverse youth participants aged 10-14 responded to each survey. Key findings from the surveys include a preference among female respondents for community- and environment-focused game goals, and game activities involving interacting with and befriending creatures, and crafting potions to tend to the island biomes. Overall, participants favored adventure games with bright colors and diverse settings, and game characters with distinct personalities and abilities.

Playtesting Interviews and Focus Groups. These sessions were conducted to gather detailed, narrative-based feedback from participants, transitioning them from players to co-designers. A *storytelling methodology* (Radke et. al, 2024) was designed and used to engage youth as designers in these sessions. Participants were encouraged to imagine backstories for their player characters, causes of creature sickness, and possible player actions, decisions, and narrative arcs. Player storytelling was analyzed to explore connections between gameplay and player values and identities. Recent focus groups identified five themes: (1) Data usage in gameplay, (2) Care for player characters, (3) Interest in creatures, (4) Desire for more exploration, and (5) Requests for in-game support. Early analysis underscores the importance of care, social interactions, data as a gameplay tool, and balancing player agency and guidance.

Together, these co-design findings emphasize themes of social connections, care for the game world and characters, expressing identity through customization and choices, and situating data as a tool for personalized or shared purposes. The co-design process has led the project toward the development of a new educational game genre focused on social, relational, and expressive gameplay.

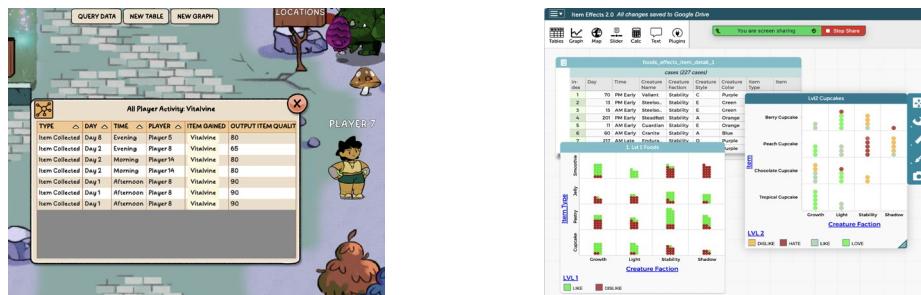
Key design features co-designed with youth participants

Game narrative and storylines were revised to focus on youth-selected themes of *Community Building* and *Balancing Island Ecosystems*, while *gameplay mechanics* were revised to place more importance on *Creature Interactions*, and in particular *Gifting*. The *world system* was updated to incorporate underwater biomes, and to link the health of the creatures (in a “mysterious sickness” storyline) to water pollution. The *data system* was updated to make use of a central fire circle on each island as an “oracle” that players can interact with to make queries of data, and get information about the health of the island or creatures.

Interactive demo session and connections to learning sciences research

Figure 3

a) In-game Data view. b) Gameplay Datasets in the CODAP Data Analysis Environment



In this interactive session, participants can playtest the latest version of the game, try out "data quests" using the in-game data tools, and explore sample gameplay datasets in the external CODAP analysis environment (Figure 3). We will share key emerging findings from co-design with youth, highlighting multiplayer game features that can situate youth data practices in a narratively rich and motivating environment, and drawing connections to learning sciences work framing data science as a social and purpose-driven endeavor.

Participants will be invited to engage in a critical reflection on our game design, and share constructive feedback on the multiplayer activities. Future research with game-based clubs will focus on youth engagement with data during gameplay and club experiences, to explore the potential for multiplayer games as informal contexts for inclusive data science education.

References

Denner, J. (2011). What Predicts Middle School Girls' Interest in Computing? *International Journal of Gender, Science and Technology*, 3(1), 53–69.

Finzer, W., & Damelin, D. (2016). Design perspective on the Common Online Data Analysis Platform (CODAP). *American Educational Research Association (AERA)*.

Gee, J. P. (2003). What Video Games Have to Teach Us About Learning and Literacy. *Computers in Entertainment*, 1(1).

Klopfer, E., Haas, J., Osterweil, S., & Rosenheck, L. (2018). *Resonant games: Design principles for learning games that connect hearts, minds, and the everyday*. MIT Press.

Konold, C., Finzer, W., & Kreetong, K. (2017). Modeling as a Core Component of Structuring Data. *Statistics Education Research Journal*, 16(2), 191–212.

Krishnamoorthy, R., Elliott, C. H., Bang, M., & Marin, A. (2021). Learning to center relational ontologies: desettling interaction analysis methods. *Proceedings of the 15th International Conference of the Learning Sciences-ICLS 2021*.

Philip, T. M., Schuler-Brown, S., & Way, W. (2013). A framework for learning about big data with mobile technologies for democratic participation: Possibilities, limitations, and unanticipated obstacles. *Technology, Knowledge and Learning*, 18(3), 103–120.

Radke, S.C., Khan, J., Hardy, L. (2024, April). Engaging Youth as Game Designers Through Storytelling. American Educational Research Association Conference, Philadelphia, PA.

Rothschild, A., Meng, A., Disalvo, C., Johnson, B., Shapiro, B. R., & Disalvo, B. (2022). Interrogating Data Work as a Community of Practice. *Proceedings of the ACM on Human-Computer Interaction*, 6(CSCW2).

Rubin, A. (2020). Learning to Reason with Data: How Did We Get Here and What Do We Know? *Journal of the Learning Sciences*, 29(1), 154–164.

Wilkerson, M. H., & Polman, J. L. (2019). Situating Data Science: Exploring How Relationships to Data Shape Learning. *Journal of the Learning Sciences*, 00(00), 1–10.

Wise, A. F. (2019). Educating Data Scientists and Data Literate Citizens for a New Generation of Data. *Journal of the Learning Sciences*, 00(00), 1–17.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 2214516. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.



Math of Facial Recognition: Co-Design of a Machine Learning and Statistics Integrated Curriculum for High School

Victoria Delaney, Stanford University, vdoch@stanford.edu
David Dobervich, Fremont High School, david_dobervich@fuhhsd.org
Isabel Sieh, Stanford University, isabelrs@stanford.edu
Megan Selbach-Allen, Stanford University, mselbach@stanford.edu

Abstract: High school teachers have growing interests in teaching about artificial intelligence (AI) and machine learning (ML), yet face challenges when curricular resources for AI/ML do not contain features that align with teachers' priorities, resources, and constraints. To meet this need, we co-designed Math of Facial Recognition (*MoFR*), a problem-based curricular unit that integrates ML, high school statistics, and facial recognition, in partnership with a high school teacher. *MoFR* contains five lessons and eight custom browser-based web applications, coined "widgets," that allow students to build statistical intuitions about how smartphones make a binary decision using data from their faces. We report theoretical underpinnings, our co-design process, the features of *MoFR*, and insights from field pilots.

Introduction

Within the last half-decade in the United States, there have been efforts to create curricula to instruct youth about how artificial intelligence (AI) and machine learning (ML) work (Drugat et al., 2022; Marques et al., 2020). However, many such resources do not consider how teachers interact with curriculum to enact classroom instruction (Remillard, 2005). Our stance is that novel AI/ML curricula intended for K-12 use must center the needs, resources, constraints, and practices (Xie et al., 2024), especially when teacher confidence about AI/ML has surfaced as a major barrier to uptake of AI/ML curricula (Chui & Chai, 2020; Sanusi et al., 2022).

To this end, we developed Math of Facial Recognition (*MoFR*), an integrated ML curriculum unit designed to meet the needs and constraints of high school statistics teachers. *MoFR* invites students to investigate, "How does a smartphone unlock itself with an image of my face?" through a five-lesson series whose core activities use open-source, browser-based web applications, or "widgets." By building intuition about facial recognition with the widgets and peer discussion, we aimed to help students build interdisciplinary knowledge of statistics, ML, and computing. Furthermore, we designed *MoFR* to be intentionally adaptable, communicating suggestions about where and how teachers could customize the lessons. In this interactive demo, we present the co-design process, theoretical perspectives, and *MoFR* curriculum. We then share insights of interest to the learning sciences community gathered from field observations when teachers enacted *MoFR*.

Theoretical perspectives

MoFR was developed on theoretical underpinnings from teacher and student perspectives. We overview two areas that informed our design: teachers' adaptations to curricula, and students' learning with personal data.

We share Brown's stance that teaching is fundamentally design work (Brown, 2002), and that designers of curricular resources should consider how teachers transform written documents to customize instruction for their individual students (Stein et al., 2007). How and to what extent teachers transform curricula depends on their *pedagogical design capacity* (Brown, 2011). On one hand, teachers consider and evaluate classroom resources: physical objects, domain representations, and domain concepts, to determine how the structure and content from written curricula support students' activities. On the other, teachers also bring to bear their own knowledge resources, including goals and beliefs, subject-matter knowledge, and pedagogical content knowledge, to evaluate the appropriateness of curricular resources. Considering that AI and ML are complex fields of study for most educators (Chui & Chai, 2020), we aimed to create *MoFR* to be accessible for teachers with a range of pedagogical design capacities for ML, statistics, and technology.

While today's AI and ML curricular resources are diverse in what topics they emphasize and the core mechanics they employ for learning (Drugat et al., 2022), there has been a growing movement to educate students about the relationship between data, algorithms, and predictions. Understanding how to work with data is already a core component of high school statistics. Recent studies that have focused on data practices more broadly have shown that when students actively collect data (Van Wart et al., 2022) and make personal connections with data (Kahn, 2022), they engage with data practices in robust and personally-meaningful ways. With this in mind, we aimed to construct tools that would enable students to use data as an interdisciplinary resource, fostering personal connections between themselves and the data used by algorithms (Lee et al., 2023).



Goals and co-design

The primary goals of *MoFR* were to (1) demonstrate the relationship between statistics, ML, and computing to students, (2) situate instruction about statistics and ML in the context of facial recognition, a well-known use of ML automation, and (3) review statistics concepts taught earlier in the academic year. Furthermore, we communicated that teachers should adapt *MoFR*'s activities to meet their goals and instructional visions.

Co-design partnership

MoFR was a curricular co-design project between the first author and Mr. D, a high school computer science and statistics teacher with a vested interest in teaching ML. Mr. D had 16 years' of classroom teaching experience in northern California at the onset of our work. In addition to his teaching duties, Mr. D coached a robotics team and participated in summer fellowships designing custom web applications for industrial settings. The first author of this paper taught high school mathematics and statistics for 7 years prior to her acceptance and participation in graduate school. While teaching, she maintained a belief that students should learn mathematics with digital technologies in ways that enable ambitious, cognitively demanding instruction. She earned a master's degree in computer science, artificial intelligence during her graduate studies.

Pre-design: Curricula review and student interest

In preparation for our co-design work, the first author conducted an in-depth review of AI and ML full curricula, classroom resources, and digital tools, to ensure that building an integrated statistics and ML curriculum was novel. Systematic reviews and database searches for AI and ML curricular resources that were available at the time were used for review (e.g., Druga et al., 2022; Marques et al., 2020; Zhou et al., 2020).

The results yielded two instances of AI and mathematics curricula (statistics curricula was not found). The first, Embeduation (Druga et al., 2022; embeduation.github.io), uses mathematical ideas about vectors, distance, and geometry to teach students about word similarity. Embeduation contains four activities and is designed for 80 minutes of instruction. The second, SmileyCluster (Wan et al., 2020), uses mathematical ideas about dimensionality, clustering, and data visualizations to teach students about k-means clustering, an unsupervised machine learning algorithm. SmileyCluster contains five activities, including an extended partner activity with the SmileyCluster system, and is designed for 150 minutes of instruction. To the best of our knowledge, neither curriculum is designed in alignment with high school mathematics standards.

After concluding that a ML and statistics integrated curriculum was novel, the first author constructed a brief questionnaire to determine which AI-based technology students were interested to learn about (on a 1-5 Likert scale). The questionnaire asked students to rate their preferences about five topics: (1) spam filtering, (2) facial recognition, (3) advertising, (4) movie recommendations, and (5) word prediction. The questionnaire was distributed to students who would be participating in the unit during the upcoming fall. Facial recognition was the most popular choice, with 92% of students responding that it would be “interesting” or “very interesting.”

Design roles and considerations

The first author and Mr. D met throughout the summer of 2022 to co-design *MoFR*. Our participation was not democratic (Roschelle et al., 2006), but rather informed by our unique strengths. The first author had experience teaching statistics in Title 1 schools and was a former AP Statistics reader. She focused on designing tasks that were approachable for teachers and students from a variety of statistical proficiencies, aligning *MoFR* to statistics standards, and integrating educative curricular resources (Davis & Krajcik, 2005) for teachers with low prior knowledge of ML. Mr. D held experience in designing web applications for learning, and as a current teacher, was more familiar with the landscape of challenges that teachers were facing. He focused on designing the widgets, core instructional activities, and curriculum sequencing.

Alignment to statistics standards and AI/ML frameworks

To align *MoFR*'s activities with standards in high school statistics, we referenced the Advanced Placement (AP) Statistics course framework, big ideas, and standards progression. Although we realized that not all students in the U.S. would have access to AP courses, AP Statistics offered the most complete course mapping of statistics standards, objectives, and enduring understandings. To ensure that *MoFR* was aligned with current thinking about ML education, we drew upon the Perception, Representation and Reasoning, Learning, and Societal Impact strands from AI4K12's Five Big Ideas framework (Touretzky et al., 2023).

Attention to features of school settings

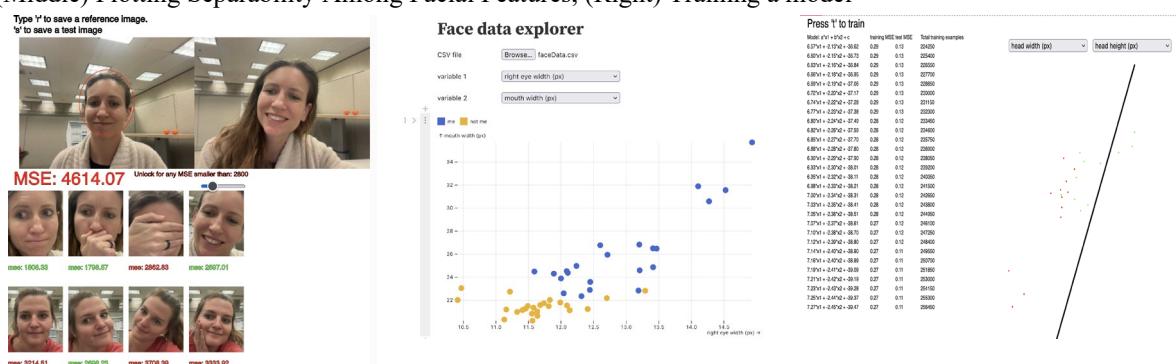
In order for *MoFR* to be desirable and easy for high school statistics teachers to integrate into their current practice, we first identified, then attended to features of school settings that could interact with *MoFR*'s classroom

implementation. A primary concern was the timing of *MoFR* with the statistical knowledge that students would likely have acquired at a given point in the school year. We settled on designing *MoFR* to be placed mid-year in a typical high school statistics course, a common point of instructional pause for many teachers. At this time, we assumed that students would have knowledge of data types and canonical data visualizations, comparing data, linear regression, sampling techniques and representativeness, and probability.

We designed the widgets to accommodate constraints that teachers and students likely faced. For instance, high schools frequently disable student access to popular media platforms (e.g., YouTube), hence Mr. D created the widgets within Observable HQ and p5.js notebooks: two javascript-based platforms that are open-access, browser-based, and do not require students to create an account. We tested the widgets throughout the summer of 2022 on Google Chromebooks, the device that most students in the fall pilot would be using, ensuring that (1) the widgets were not blocked by IT infrastructure, and (2) the widgets did not lag when they used students' webcams to create models with their facial data. Figure 1 illustrates of some of the widgets.

Figure 1

Widgets in the *MoFR* Curriculum. (Left) Comparing Similarity Between Images Using Mean-Squared Error, (Middle) Plotting Separability Among Facial Features, (Right) Training a model



Math of facial recognition

The final *MoFR* curricular unit contains five lessons whose activities take roughly 90 minutes of classroom instruction. Each lesson contains a core exploration activity where students work with a partner to explore some aspect of facial recognition and ML. Each lesson provides supplementary resources, such as slides to present new ML content and/or review statistics, discussion, and closure. *MoFR*'s teacher-facing materials provide guidance on where to shorten or extend activities to fit the confines of scheduling.

The first lesson introduces students to pixels as units of measurement in images, image comparison, and statistical error as a measure of similarity. Students establish an error threshold between their own facial images and a partner's using two methods: pixel brightness and facial distances. Students learn that pixel brightness is more easily subject to biases from features of the environment.

The second lesson establishes that algorithms must account for variability in students' appearances. Students attempt to create separable data sets between themselves and a partner along two facial dimensions, and discuss the real-world consequences of false positives and negatives when algorithms predict incorrectly.

The third lesson deepens students' understanding of (linear) decision boundaries. They learn the difference between regression and classification problems, how to interpret multivariate equations, and explore manually tuning the parameters of a linear classifier.

The fourth lesson illustrates why computing power is needed for facial recognition: because human faces contain too many variables, parameters, and dimensions for humans to optimize by hand. Students train a ML model with facial feature variables, observing how machines fit classification models to optimize accuracy and minimize statistical error over many iterations of training.

The fifth lesson focuses on ethical dilemmas in facial recognition. The activities use historical blunders in face recognition to develop students' critical capacity toward AI and ML, encouraging them to consider features of data that bias algorithmic outcomes. As a culminating activity, students create a Data Bill of Rights.

Field observations and future work

MoFR was tested in public, charter, and private schools in northern California, U.S.A., in the winter of 2022-23. The first author conducted field observations and pre-post interviews with three teachers in addition to Mr. D's implementation of *MoFR*. Each teacher had at least five years' experience teaching with digital technologies, had



experience teaching statistics, and desired to teach about ML, even though they did not necessarily have prior knowledge of it. While the analysis of the classroom implementations is not the current focus, we conclude with a summary of insights gained while implementing *MoFR* and implications for future work.

All teachers reported that *MoFR*'s widgets and activities supported student inquiry about ML and urged students to think more deeply about how algorithms are designed to interpret the facial features of humans using mathematics and statistics. To varying degrees, all teachers were able to adapt *MoFR* to suit their instructional needs. However, some tensions arose that will become the focus of future development. Two teachers reported that the curriculum offloaded statistical ideas onto the widgets too quickly, and that students would have benefitted with more hands-on practice with statistics before using the widgets. One teacher further observed that his students became discouraged if they could not find combinations of facial features that produced a fairly accurate ML model. Both insights raise questions about the relationship between technology, ML, and data set design, and the work that written curriculum must do to support teachers grappling with pedagogy in these interconnected fields. We intend to explore these insights at length in future work.

References

Brown, M. W. (2011). The teacher–tool relationship: Theorizing the design and use of curriculum materials. In *Mathematics teachers at work* (pp. 37-56). Routledge.

Brown, M. W. (2002). *Teaching by design: Understanding the intersection between teacher practice and the design of curricular innovations*. Northwestern University.

Chiu, T. K., & Chai, C. S. (2020). Sustainable curriculum planning for artificial intelligence education: A self-determination theory perspective. *Sustainability*, 12(14), 5568.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational researcher*, 34(3), 3-14.

Drugă, S., Otero, N., & Ko, A. J. (2022, July). The landscape of teaching resources for ai education. In *Proceedings of the 27th ACM Conference on on Innovation and Technology in Computer Science Education Vol. 1* (pp. 96-102).

Kahn, J. (2022). Learning at the intersection of self and society: The family geobiography as a context for data science education. In *Situating Data Science* (pp. 57-80). Routledge.

Lee, V. R., Sarin, P., Sieh, I., & Fuloria, A. (2023). Addressing the Data Set Dilemma With Personally Relevant Data Generation and Distributed Labeling in the Classroom. In *Proceedings of the 16th International Conference on Computer-Supported Collaborative Learning-CSCL 2023*, pp. 420-423. International Society of the Learning Sciences.

Marques, L. S., Gresse von Wangenheim, C., & Hauck, J. C. (2020). Teaching machine learning in school: A systematic mapping of the state of the art. *Informatics in Education*, 19(2), 283-321.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of educational research*, 75(2), 211-246.

Roschelle, J., Penuel, W., & Shechtman, N. (2006). Co-design of Innovations with Teachers: Definition and Dynamics. In *Proceedings of the 2nd International Conference of the Learning Sciences, Bloomington, Indiana, USA*: International Society of the Learning Sciences.

Sanusi, I. T., Oyelere, S. S., & Omidiara, J. O. (2022). Exploring teachers' preconceptions of teaching machine learning in high school: A preliminary insight from Africa. *Computers and Education Open*, 3, 100072.

Stein, M. K., Remillard, J., & Smith, M. S. (2007). How curriculum influences student learning. *Second handbook of research on mathematics teaching and learning*, 1(1), 319-370.

Touretzky, D., Gardner-McCune, C., & Seehorn, D. (2023). Machine learning and the five big ideas in AI. *International Journal of Artificial Intelligence in Education*, 33(2), 233-266.

Van Wart, S., Lanouette, K., & Parikh, T. S. (2022). Scripts and counterscripts in community-based data science: Participatory digital mapping and the pursuit of a third space. In *Situating Data Science* (pp. 127-153). Routledge.

Wan, X., Zhou, X., Ye, Z., Mortensen, C. K., & Bai, Z. (2020, June). SmileyCluster: supporting accessible machine learning in K-12 scientific discovery. In *proceedings of the Interaction Design and Children Conference* (pp. 23-35).

Xie, B., Sarin, P., Wolf, J., Garcia, R. C., Delaney, V., Sieh, I., Fuloria, A., Dennison, D.V., Bywater, C., & Lee, V. R. (2024). Co-designing AI Education Curriculum with Cross-Disciplinary High School Teachers.

Zhou, X., Van Brummelen, J., & Lin, P. (2020). Designing AI learning experiences for K-12: Emerging works, future opportunities and a design framework. *arXiv preprint arXiv:2009.10228*.

Workshops





Bite-Sized Assessments: Creating Micro-credentials for Buffalo Chicken Wings

Sam Abramovich, University at Buffalo, samuelab@buffalo.edu
Peter Wardrip, University of Wisconsin – Madison, wardrip@wisc.edu

Abstract: While most Learning Scientists know the value of assessment for supporting learning, their understanding is often limited to experiences with large and complicated assessments (e.g., tests, grades, evaluations) or feedback that is complicated to deliver (e.g., teacher delivered formative feedback, peer feedback using rubrics). However, assessments can be small, simple, and delivered efficiently for any setting. Attendees will learn how to create micro-credentials, short-format credentials that provide recognition for knowledge and skills that can be earned more quickly than traditional credentials (Olcott, 2022). They will then apply this knowledge in creating micro-credentials for Buffalo Chicken Wings, a culinary highlight of the 2024 ISLS Annual Meeting. In addition, attendees will be able to design ways that micro-credentials could be used to solve educational challenges or contribute to research that they are addressing. With some confidence, we claim that this will be the most delicious workshop in the history of the ISLS.

Introduction

While almost everyone understands the value and need for high-quality assessments, this knowledge often does not correlate with experience and comfort in creating and implementing assessments. A likely reason for this ironic incongruence is that people often have a dislike or worry about assessment, usually from personal experiences where they underwent some type of a high-stakes test that caused them personal stress or a belief that the assessment did not represent their actual skill or knowledge (i.e., the assessment was invalid). Even Learning Scientists, who understand and may even use some type of assessment in their research, often approach the design of assessments with trepidation or a lack of enthusiasm. However, rather than believe that assessment is simply a tool that has to be used in some learning settings, we argue that assessment can be both a learning tool and fun for the assessor, the assessed, and the assessment designer. The aim of this workshop is to expose learning scientists to designing micro-credentials, a validated assessment processes that can be applied to a universally understood and fun (i.e., delicious) setting. We believe that we can make significant progress in increasing the number of learning scientists who then use these small assessments to strengthen their research agendas. Similarly, the combination of foods and academia is a well-established way to explore outside-the-box thinking in academic pursuits (Cernea, 2006).

Micro-credentials

The concept of a badge representing a skill or experience has been around for a very long time, as can be seen in military representation (e.g., ranks of individual soldiers, an insignia of a group of soldiers with special training). Outside of the military or law enforcement, perhaps the most common example of an analog badge is that of Scouts (e.g., Boy Scouts of America, Pramuka Movement of Indonesia, Bangladesh Scouts), who use ‘merit badges’ as a motivator, summative assessment, and skill tree for their participants.

Micro-credentials borrow a basic structure of traditional badging while utilizing the affordances of internet-based technology to create a relatively new form of assessment. Similar to the achievement and reward systems prevalent in video games, micro-credentials are designed to recognize and validate a wide range of skills and accomplishments with the secondary goal to create a flexible, accessible means of acknowledging diverse forms of learning and achievement, reflecting the evolving landscape of education and professional development. Proving their universal applicability, micro-credentials have gained traction beyond the realm of education, finding applications in corporate training, professional development, and as integral components of gamification strategies in different sectors. Their versatility and adaptability made them an appealing tool for both learners and educators, bridging the gap between formal education and lifelong learning.

Research on micro-credentials has resulted in a number of critical findings (Wolz et al., 2021). Most importantly, micro-credentials are best applied to learning settings where there is a need for additional assessment (Abramovich, 2016). In other words, micro-credentials are not replacements for functional credentials such as degrees, grades, or certifications. Instead, they are best applied where there is no current assessment but where one could be added to increase the value of the learning that is occurring (Gauthier, 2020). For example, these may be co-curricular activities that are not normally assessed or skills that an individual has that are not recognized



by others (Wardrip et al., 2016). The creation of micro-credentials is also a learning process for the designer (Berry et al., 2016). Educators who want to issue credentials must consider fundamentals of good learning, such as recognizing what is being learned and what is evidence that it was learned (French & Berry, 2017). For learners who are issuing credentials to themselves or their peers, their design of the micro-credentials includes recognizing what is being learned, being able to talk about that learning, and then engaging in that learning process.

What all micro-credentials have in common is their small size. These are not credentials that represent years of learning or complex skill trees. Instead, the intention is that they are so small that they can be rapidly developed and then integrated into setting where their implementation represents little additional labor. Consequently, micro-credentials can be inserted into settings where their addition adds to the enjoyment of the experience, similar to gamification. Because they are easy to create and can add fun to a setting, we argue that micro-credential design and implementation are underused for teaching good assessment practices since they can be applied in almost any learning opportunity. To prove this, this workshop will have participants learn to create micro-credentials for something that many would think is incompatible with good assessment design, the Buffalo Chicken Wing.

The Buffalo Chicken Wing

The Buffalo Wing is a ubiquitous food in the United States and Canada, and can be found in many international settings also. Its origins are debated, but many believe that their creation was in 1964 when a owner of a local establishment in Buffalo concocted the dish as a late-night snack for her son and his friends by deep-frying leftover chicken wings and tossing them in sauce comprised of peppers and butter (National Chicken Council, 2017, para. 1). This simple yet innovative recipe has transformed a previously underappreciated part of the chicken into a beloved appetizer and bar food staple. The name "Buffalo wings" was derived from the city of their inception and has become synonymous with American comfort food, inspiring countless variations and a devoted following who regularly come to Buffalo for the International Wing Festival.

The Buffalo Chicken Wing, referred to as Wings in the local vernacular, is an ideal food for this workshop. First, it is the most iconic part of Buffalo's food culture, allowing participants to engage in part of what makes Buffalo unique. We expect that participants in the workshop will have learned a greater appreciation of western New York as part of their exposure to this food. This is an aim that we believe is core to being a Learning Scientist: an appreciation for local culture and customs. Second, the Buffalo Chicken wing is a food that has generated two well-established assessment related questions:

- What makes a good Buffalo Wing? At first, they may seem an impossible task for assessment design, since taste is subjective. However, we will guide participants into breaking down an assessment for a Buffalo Wing into micro-assessments that can be then used either for a desired wing quality or in consensus to determine overall wing tastiness.
- Who has the best chicken wing in Buffalo? Although local connoisseurs of chicken wings do have preferred restaurants (Visit Buffalo Niagara, n.d.), even amongst them there is no consensus best wing. We will provide Buffalo wings from three of the most famous wing restaurants in western New York (Anchor Bar, Duff's, Elmo's) to help answer this type of question. But we note that this type of question is quite common when extrapolated to different categories, which should allow workshop participants to build connections between what they accomplish in the workshop and their research agenda.

Explanation of activities

In this workshop, we invite participants to come together and explore assessment and evaluation of Buffalo chicken wings through three general formats: mini-talks, engagement in micro-credential design activities and small group discussions. The workshop will gather 5-25 participants. The following is a general outline of the half-day session (that will be adapted to account for the exact number of participants and the background/interests of the participants):

1. Mini-talks - Some participants will have an opportunity to give a brief 5-minute presentation about their connection to assessment. The goal of this activity is to introduce some diversity of approaches and tools that exist in the field, the theoretical commitments that some of the participants may possess and get to know the participants in the workshops.
2. Assessment of the Wings - Participants will engage in designing micro-credentials for wings in general and then for the best made wing. Obviously, this will include eating a large number of wings, which will be provided by the workshop organizers. As we enjoy the wings, several assessment



design protocols will be reviewed. For example, we expect that Likert-Scale Design (Joshi et al., 2015), Classical Test Theory (Hambleton & Jones, 1993), Evidence Centered Design (Mislevy et al., 2003), and Item Response Theory (Rusch et al., 2017) may apply in the workshop. The number of models/theories will be selected based on the number of participants in the workshop. Attendees will be grouped so that they may have a turn to apply all of the reviewed assessment models.

For example, Group A will apply an Evidence Centered Design approach to creating a micro-credential. At the same time Group B will apply a Likert Scale model for a wing assessment. Each group will be given a checklist to ensure reliable and valid assessment design. Then, after a fixed period of time, groups will switch. After multiple rotations, participants could have the experience of designing micro-credentials at least twice, and more if we choose more assessment models.

3. Small Group Discussions: Using protocols (McDonal et al., 2015) to loosely structure small group discussions, we will engage the participants in discussions related to assessment. Using our concrete experiences of eating and assessing with wings, we will focus on questions related to research (e.g., What learning theories are instantiated in wing eating? What issues of validity and reliability might we consider with a tool for evaluating a wing? What might be altered to increase learning and engagement?) as well as practice (e.g., What is the model of use for the assessment tools? What other foods are well-suited/ill-suited for these tools? How might they be altered for educational use?). While the concrete assessments will provide a clear referent for discussions, we will encourage the conversations to move beyond those examples to draw in participants' own experience and expertise related to using assessment.

At the end of the workshop, we will have addressed the following goals:

- *Collect and share work that is currently being carried out in the field through the participants in the workshop, with consideration on how micro-credentials might be incorporated into that work.*
- *Suggest principles that can guide the choice, design, and use of assessments in Learning Sciences research.*
- *Identify gaps that exist related to how Learning Scientists can leverage existing research on assessment design.*

Limitations

For a workshop of this kind, we recognize that there are a number of factors that may preclude participants from joining.

1. Limited Appetites – We understand that some Learning Scientists may not have much of an appetite for Buffalo Wings, both physically and mentally. While we understand that much of the Learning Sciences should be maximally inclusive, this is one area where we take a firm stand. Simply put, if you are not interested in Buffalo Wings or Micro-credentials then this workshop is not for you. However, we will invite all potential participants, regardless of whether they have a passing interest in assessment or believe that wings should be eaten with Ranch dressing (a faux pas in Buffalo, where only Blue Cheese dressing is served with wings).
2. Food Allergies – Although there is no research on this specific topic, we can reasonably expect that a number of Learning Scientists have some food intolerances or allergies that may impact their ability to participate. Specifically, we foresee that an issue with vegan or vegetarians. We wish to



assure the conference organizers that we will provide vegan wing alternatives since we do wish to preclude those who do not wish to eat meat.

If participants want a beer to go with their wings, then that's their responsibility.

Future workshops

If accepted as a workshop for ISLS 2024, we hope to make this workshop a recurring feature of future Annual Meetings. The target micro-credential foods for ISLS 2025 could be Mämmi (traditional Finnish dessert), Lonkerö (a Finnish long drink), or Salmiakki (Finnish salty licorice). Lessons learned from the 2024 version of the workshop will be applied to this future workshop, which we will hope will establish a tradition for all future Annual Meetings.

In addition, the authors of this workshop proposal are experts in assessments and committed to the longevity of the ISLS, and so this proposal represents a commitment to this workshop and future ones. Consequently, accepting this proposal is a guaranteed step in establishing a connection between local foods and the Learning Sciences – an incredibly fun way to continue the interdisciplinary nature of our field.

References

Abramovich, S. (2016). Understanding digital badges in higher education through assessment. *On the Horizon*, 24(1), 126-131.

Berry, B., Airhart, K. M., & Byrd, P. A. (2016). Microcredentials: Teacher learning transformed. *Phi Delta Kappan*, 98(3), 34-40.

Cerneia, R. F. (Ed.). (2006). *The Great Latke-Hamantash Debate*. University of Chicago Press.

French, D., & Berry, B. (2017). Teachers, Micro-Credentials, and the Performance Assessment Movement. *Voices in Urban Education*, 46, 37-43.

Gauthier, T. (2020). The value of microcredentials: The employer's perspective. *The Journal of Competency-Based Education*, 5(2).

Hambleton, R. K., & Jones, R. W. (1993). Comparison of classical test theory and item response theory and their applications to test development. *Educational measurement: issues and practice*, 12(3), 38-47.

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology*, 7(4), 396.

McDonald, J. P., Mohr, N., Dichter, A., & McDonald, E. C. (2015). *The power of protocols: An educator's guide to better practice*. Teachers College Press.

Mislevy, R. J., Almond, R. G., & Lukas, J. F. (2003). A brief introduction to evidence-centered design. *ETS Research Report Series*, 2003(1), i-29.

National Chicken Council. (2017, January 24). *Chicken Wing History*. Retrieved December 7, 2023, from <https://www.nationalchickencouncil.org/chicken-wing-history/>

Rusch, T., Lowry, P. B., Mair, P., & Treiblmaier, H. (2017). Breaking free from the limitations of classical test theory: Developing and measuring information systems scales using item response theory. *Information & Management*, 54(2), 189-203.

Visit Buffalo Niagara. (n.d.) Top 13 Places for the Best Wings in Buffalo. Retrieved December 8, 2023, from <https://www.visitbuffalonagara.com/crawl/buffalo-wing-trail/>

Wardrip, P. S., Abramovich, S., Kim, Y. J., & Bathgate, M. (2016). Taking badges to school: A school-based badge system and its impact on participating teachers. *Computers & Education*, 95, 239-253.

Wolz, E., Gottlieb, M., & Pongratz, H. (2021). Digital credentials in higher education institutions: A literature review. *Innovation Through Information Systems: Volume III: A Collection of Latest Research on Management Issues*, 125-140.



A Gathering to Synthesize, Critically Examine, and Envision New Horizons for Learning Sciences Research on “Failure” and Learning

David DeLiema, University of Minnesota, ddeliema@umn.edu

Maleka Donaldson, Smith College, mdonaldson@smith.edu

Luis Morales-Navarro, University of Pennsylvania, luismn@upenn.edu

Colin Hennessy Elliott, Drexel University, ch3457@drexel.edu

Amber Simpson, Binghamton University, asimpson@binghamton.edu

Abstract: This workshop brings together learning scientists and educators interested in synthesizing, critiquing, and charting new horizons for research on “failure” and learning. Workshop participants will have opportunities to share their summaries and critiques of existing literature, gather together in small groups to critically reflect on new syntheses and new openings in this literature, and then work together to document and prioritize urgent research questions and generative research methods for this area of work.

Overall focus of the workshop

This workshop focuses on a topic persistently covered in public and academic discourse on teaching and learning: the relationship between “failure” and learning. This word is packed with a wide array of meanings, and likely feels different to each person who interacts with it. By extension, there is no consensus in the research literature nor in public vernacular about how to refer to the various experiences surrounding failure. Words such as impasse, breakdown, problem, incompatibility, discrepancy, mistake, bug, misconception, and on and on have all featured prominently in the research literature, and each uniquely accents different facets of the experience. At the same time, they all in some core sense refer to a situation in which someone’s process or outcome falls out of sync with an expectation, ideal, or goal. Taking this heterogeneity – and some degree of common ground – head-on in this workshop, we will gather together with researchers and educators interested in contemplating, studying, and/or supporting the experience of failure in learning. Our plan is to synthesize work from the learning sciences and related fields around failure, make space to critically reflect on the gaps and shortcomings in these lines of work, and chart new theoretical, methodological, and practical directions.

Organizing team

We are a collective of early-career researchers who have studied failure and learning in our prior work. We come from different labs and use different methodologies in different disciplinary contexts to study failure and learning. This workshop is thus a bridge-building opportunity for disparate but synergistic research threads among our organizing team and for participants who join the workshop. Collectively, our work on failure and learning spans student age ranges from early education (DeLiema et al., 2023; Donaldson, 2021) to elementary/middle school (DeLiema et al., 2023; Hennessy Elliott et al., 2023; Simpson et al., 2019) and high school (Donaldson, 2023; Hennessy Elliott & Ma, in prep; Morales-Navarro et al., 2023), and much of this work covers the perspectives of adult educators and parents (DeLiema et al., 2023; Donaldson, 2019; Hennessy Elliott et al., 2023; Maltese et al., 2018). Disciplinary contexts in our work on failure include literacy, mathematics, makerspaces, computer science, outdoor nature play, robotics, and fictional children’s books. We have further drawn on disparate methods, including portraiture (Donaldson, 2021), interaction analysis (DeLiema et al., 2023; Hennessy Elliott et al., 2023), positioning theory (Fong et al., 2023; Simpson et al., 2017), surveys (Morales-Navarro et al., 2023), content analyses (Donaldson et al., 2023), interviewing (Maltese et al., 2018), and conjecture mapping (DeLiema et al., 2023). We are hopeful that our combined expertise stretching across these age ranges, disciplinary contexts, and research methods will allow us to provide a welcoming space to a wide range of attendees, and spark new conversations and reflections in this research area.

Theoretical approach and relevance to the learning sciences

There is a long history of scholarship in and outside of the learning sciences that addresses the relationship between failure and learning. Foundational scholarship re-framing misconceptions and examining longer-term learning trajectories through the preparation for future learning lens in many ways are synergistic with contemporary learning sciences threads of work on productive failure (Sinha & Kapur, 2021) and invented science (Russ & Berland, 2019). At the same time, there is work that examines how social contexts and activity frames shape moments of failure, whether the playful and collaborative nature of a space (Ryoo & Kekelis, 2018;



Williams-Pierce, 2019), the intentional design of errors for peers to resolve (Fields et al., 2021), the overall error climate of a class (Steuer et al., 2013), or the culture of mistakes in a classroom (Donaldson, 2021). Conversely, parts of the learning sciences community have continued to embrace the methodological position that failures of infrastructures, or breakdowns, reveal so much about the relational nature of the infrastructures themselves (Starr, 1999 in Hladik, et al., 2023). There are additional threads of work resonant with investigations into power in learning settings (e.g., Esmonde & Booker, 2017), including framings from queer theory that challenge what it even means to fail (Halberstam, 2011; Ruberg, 2017), perspectives that recognize the mosaic of mixed and multiple outcomes of failure (Anderson et al., 2019; DeLiema et al., 2023), and research on how failure is noticed and who leads that noticing (Fong et al., 2023; Hennessy Elliott & Ma, in prep). Implicit in this work is the underpinning sociopolitical question, “When is it okay to fail and when is it not?” and the related question, “Who is allowed to fail and who is not?”

Meanwhile, the concept of failure is a frequent part of public and academic discourse. There are ongoing calls for “fast failure” in the software industry and guides to becoming an “elite failure practitioner” in business (Edmondson, 2023), historical and narrative accounts of the heterogeneous kinds of failures that spur creativity (Lewis, 2014), a new 4-part series on failure from the podcast Freakonomics, and numerous works of art on the topic. Even further, there is a philosophical treatise arguing for the necessity of errors (Roberts, 2011) and extensive work on how to avert failures in complex and high-stakes technological systems (Reason, 1990). Yet, while the business fields are devising new ways to talk about failures, and educational researchers study failure in learning settings, racist policy continues to lead to schools getting labeled as “failing” and being closed down (Ewing, 2018). Against this backdrop, psychological research on grit and growth mindset has proliferated as meta narratives in school that ask children in the face of difficulties to be more resilient and/or focused on skill development. These have been critiqued for presenting a false meritocracy (Duncan-Andrade, 2009; Au, 2016), eclipsing historical suffering and rebellion (Love, 2019), and ignoring resiliency in most contexts (Rose, 2015; Kundu, 2020). This individualized, and psychologized, focus on failure does not “compensate for adverse circumstances” but instead reifies existing privilege (Audley & Donaldson, 2022).

What does this work in the learning sciences, and the empirical work and narratives in related disciplines and in the public – especially the critiques – mean for research on failure and learning? What have we learned so far, and what new work on failure and learning is urgently needed? Centering these overarching questions, we recognize that there is rarely enough opportunity to talk across these frameworks, disciplinary contexts, activity contexts, and research methods. There are vital questions to consider together. What are the core learnings in the existing literature on failure and learning? What questions in this area are we not asking? What is leaving us feeling uneasy or uncertain about work in this area? What is failure? Can we reach a consensus in defining it, and should we? Is failure a reasonable umbrella word to use, and if not, what are important considerations for selecting alternatives? Who gets to decide what counts as failure in particular situations? How does power shape that interactional process? How do history and systems, and the present-day inequities they shape, relate to students’ experiences with failure in learning? What bridges might we build to adjacent literatures and frameworks? What new analytical approaches might open up new horizons?

Outline of planned activities

The workshop will take place in three parts, each of which will run for about 2 hours, with breaks interspersed throughout and between each part. The overall flow of the workshop aims to give participants a voice to share their personal experiences with failure and learning, critically synthesize threads of the literature, and envision new research and practice-based directions.

Part 1: Storytelling, synthesizing, and provoking

In the first part of the workshop, we will gather together, make space for introductions, and then meet in small groups to share personal experiences with failure in learning, and start to raise questions about whether the parts of those stories that feel important are reflected/studied in the research literature. We will catalyze these discussions by sharing quotes from research, media, and our own work. Workshop coordinators will share overall themes from these initial sessions with the full workshop. We will then move to the literature synthesis. All participants who sign up for the workshop will be invited ahead of time to create a short, roughly 3-5-minute presentation covering a particular thread of the research literature on failure and learning, including focusing on distinct domains (debugging, science experimentation, kinesiology, etc.), activity frames/designs (productive failure, play, games, makerspaces), and research methods (interaction analysis, portraiture, etc.). Each presenter will cover a few questions: How is failure defined in this area of work? What are the valued/measured outcomes of this work? What are the key findings in this area? What critiques of this literature would you center? What do you see as the core questions not being investigated in this area of work? These talks are meant to provide



workshop participants with pathways to literature and findings they may not be familiar with, and provoke reflection on core questions centered in the workshop. Following each talk, workshop participants will be given time to reflect and write, and if they wish, share their observations in a common hub (e.g., Miro).

Part 2: Focused small-group reflections

Participants will then meet in groups of 3 people, and work for 30 minutes to share what is on their minds about the morning's talks and about how they are thinking about failure and learning. The purpose of the small group work will be to really listen to each other's reflections and generate questions, explore research methods, and critique the literature. We will then rotate to form new groups of 3, and repeat this process a third time. The intention is to allow participants to engage in deep dialogue about this topic with a wide range of attendees, learn about each other's perspectives, and generate concrete reflections to share with the wider group.

Part 3: Group synthesis and charting new directions

We will conclude with time for everyone to work individually for a stretch of time, whether memoing for themselves, representing their thinking in a diagram, or spending time exploring a new reading or project. We will then gather together as a full group and give each person time to share their reflections on failure and learning. We will provide question prompts that each speaker will be welcome to use or ignore. These include: How are you thinking about defining failure? What are the urgent next questions to address in this area of work? How do you think we should be studying this process moving forward? Workshop organizers will focus on documenting participants' reflections, gathering artifacts, and then synthesizing the group's thinking in a final share-out. Finally, the workshop will conclude with a group discussion about next steps, which might include collaborating on a position paper, working on a special issue, or fostering small group collaborations.

Intended audience

The workshop will be open to all educational researchers, educators, educational leaders, etc. who are interested in joining a discussion about failure and learning, and we plan to invite a wide array of participants who focus on different disciplinary domains, engage in different practice-based work, use different research methods, etc.

Duration and format of the event

The workshop will run for a full day and follow the format described above.

Participation requirements

No requirements need to be met to participate in the workshop. We welcome participants who have engaged in research or practice-based work on failure and learning previously, and participants who are brand new to the topic and interested in exploring it further in their research, teaching, leadership, etc.

Relationship to similar events (e.g., at CSCL or ISLS)

There have been many sessions at ISLS over the years that focus on productive failure, debugging, etc., but we are not aware of a prior workshop at ISLS or CSCL that has focused on failure and learning. We hope that this can become a generative space for researchers and teachers interested in this topic to gather together, build community, and critically take stock of what has been accomplished so far and where this work might go next.

Facilities and equipment required

We anticipate being able to use a standard classroom with a projector, microphone, and movable tables and chairs. We will further host a zoom room for remote participants, and rotate among the workshop coordinators to make sure that someone is always present to facilitate and liaison between the two settings.

Minimum and maximum number of participants needed

Beyond the workshop organizers, we hope for anywhere between 10 to 25 additional participants.

References

Anderson, A., Goeke, M., Simpson, A. M., & Maltese, A. V. (2019). Where should learners struggle? Developing a failure mindset through maker activities. *Connected Science Learning*, 1(12).

Au, W. (2016). Meritocracy 2.0: High-Stakes, Standardized Testing as a Racial Project of Neoliberal Multiculturalism. *Educational Policy*, 30(1), 39–62.



Audley, S., & Donaldson, M. (2022). When to grit and when to quit: (How) should grit be taught in K-12 classrooms? *Theory Into Practice*, 61(3), 265-276.

DeLiema, D., Kwon, Y., Chisholm, A., Williams, I., Dahn, M., Flood, V., Abrahamson, D., & Steen, F. (2023). A multi-dimensional framework for documenting students' heterogeneous experiences with programming bugs. *Cognition & Instruction*, 41(2), 158- 200.

Donaldson, M. (2021). *From oops to aha: Portraits of learning from mistakes in Kindergarten*. Rowman & Littlefield.

Donaldson, M. (2023). Student mistakes in elite school classrooms: Teacher reflections and reported instructional strategies. *Journal of Educational Research and Practice*, 13(1), 13.

Duncan-Andrade, J. (2009). Note to educators: Hope required when growing roses in concrete. *Harvard Educational Review*, 79(2), 181-194.

Edmondson, A. C. (2023). *Right kind of wrong: The science of failing well*. Simon and Schuster.

Esmonde, I., & Booker, A. N. (Eds.). (2016). Power and privilege in the learning sciences: Critical and sociocultural theories of learning. *Taylor & Francis*.

Fields, D. A., Kafai, Y. B., Morales-Navarro, L., & Walker, J. T. (2021). Debugging by design: A constructionist approach to high school students' crafting and coding of electronic textiles as failure artefacts. *British Journal of Educational Technology*, 52(3), 1078-1092.

Fong, M. M., DeLiema, D., Flood, V. J., & Walker-van Aalst, O. (2023). Contesting sociocomputational norms: Computer programming instructors and students' co- operative stance-taking around refactoring. *International Journal of Computer-supported Collaborative Learning*.

Halberstam, J. (2011). *The queer art of failure*. Duke University Press.

Hennessy Elliott, C., Gendreau Chakarov, A., Bush, J. B., Nixon, J., & Recker, M. (2023). Toward a debugging pedagogy: helping students learn to get unstuck with physical computing systems. *Information and Learning Sciences*, 124(1/2), 1-24.

Hladik, S., Sengupta, P., & Shanahan, M. C. (2023). Museum facilitator practice as infrastructure design work for public computing. *Cognition and Instruction*, 41(2), 248-289.

Kundu, A. (2020). The power of student agency: Looking beyond grit to close the opportunity gap. *Teachers College Press*.

Leigh Starr, S. (1999). The ethnography of infrastructure. *American Behavioral Scientist*, 43(3), 377-391.

Lewis, S. (2014). *The rise: Creativity, the gift of failure, and the search for mastery*. Simon and Schuster.

Love, B. L. (2019). *We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom*. Beacon press.

Maltese, A. V., Simpson, A., & Anderson, A. (2018). Failing to learn: The impact of failures during making activities. *Thinking Skills and Creativity*, 30, 116-124.

Morales-Navarro, L., Giang, M. T., Fields, D. A., & Kafai, Y. B. (2023). Connecting beliefs, mindsets, anxiety and self-efficacy in computer science learning: an instrument for capturing secondary school students' self-beliefs. *Computer Science Education*, 1-27.

Reason, J. (1990). *Human error*. Cambridge University Press.

Roberts, J. (2011). *The necessity of errors*. Verso Books.

Rose, M. (2015). *Why teaching kids to have 'grit' isn't always a good thing*. Washington Post.

Ruberg, B. (2017). Playing to lose: The queer art of failing at video games. In J. Malkowski and R. M. Treaandrea (Eds.) *Gaming Representation. Race, Gender and Sexuality in Video Games* (pp. 197-211). Indiana University Press.

Russ, R. S., & Berland, L. K. (2019). Invented science: A framework for discussing a persistent problem of practice. *Journal of the Learning Sciences*, 28(3), 279-301.

Ryoo, J. J., & Kekelis, L. (2018). Reframing "failure" in making: The value of play, social relationships, and ownership. *Journal of Youth Development*, 13(4), 49-67.

Simpson, A., Anderson, A., & Maltese, A. V. (2019). Caught on camera: Youth and educators' noticing of and responding to failure within making contexts. *Journal of Science Education and Technology*, 28, 480-492.

Sinha, T., & Kapur, M. (2021). When problem solving followed by instruction works: Evidence for productive failure. *Review of Educational Research*, 91(5), 761-798.

Steuer, G., Rosentritt-Brunn, G., & Dresel, M. (2013). Dealing with errors in mathematics classrooms: Structure and relevance of perceived error climate. *Contemporary Educational Psychology*, 38(3), 196-210.

Williams-Pierce, C. (2019). Designing for mathematical play: failure and feedback. *Information and Learning Sciences*, 120(9/10), 589-610.



Cultivating Ensembles at ISLS

Marisa A. Holzapfel, Carl von Ossietzky University of Oldenburg, Germany, marisa.alena.holzapfel@uni-oldenburg.de

Carolyn D. Sealfon, Minerva University and Ronin Institute, carolyn.sealfon@roninstitute.org

Barbara J. Natalizio, University of Massachusetts Chan Medical School and Ronin Institute, barbara.natalizio@roninstitute.org

Raquell M. Holmes, improvscience and East Side Institute, raquell@improvscience.org

Abstract: Large conference attendees often miss interesting sessions because of the conflicts of parallel programming. The authors, Cultivating Ensembles' organizers, will model their innovative and intentional approach to this issue with the ISLS 2024 participants. We offer to lead a series of ongoing brief engagement activities throughout ISLS 2024 that allow participants to share their experiences from different sessions. We use a documented playful and inclusive approach to engage the broadest audience.

Organizers

The Cultivating Ensembles Organizing Committee (CE; formerly Cultivating Ensembles in STEM Education and Research) brings together people who create powerful learning environments through intentional collaboration across the arts, humanities, and sciences. Activities include bi-annual conferences, community meetings, and coffee chats. CE creates a unique professional development environment where innovators learn from each other's practice and discover and celebrate the interweaving of sciences, technologies, humanities, and the arts as human activities. People who collectively imagine, create, and explore our world are the heart of science, technology, engineering, mathematics, medicine, and the multitude of arts (Sealfon et al., 2023). Learn more about us at cultivatingensembles.org.

Event description

Organizers of Cultivating Ensembles (Holmes, 2022) welcome the Learning Sciences community in an interactive discovery of ensemble-building and its possibilities for research and education. We promote co-creative, inclusive environments where learning and growth occurs among individuals as a community, with collaborative, reflective inquiry and performance (Schon, 1983; Jaworski, 2006; Lobman, 2010; Holzman, 2016). At large conferences, participants sometimes suffer from the "Fear of Missing Out" (FOMO). To overcome this, we often have to accept the "Certainty of Missing Out" (COMO). To help manage COMO, Cultivating Ensembles builds "share out" sessions into its conference schedules, where participants share what they learned in different parallel sessions, or even what they heard in the same session differently. These sessions use play and performance as collaborative exploration, an approach that views learning as a creative, social act (Knudsen and Shechtman, 2011; Martinez, 2011; Sawyer, R. K. 2004).

In this workshop, we invite the Learning Sciences community to join us in a series of dynamic short co-generative sharing activities during the conference in which we will build an ensemble that explores through play the following questions (Sealfon et al., 2023; Hadzigeorgiou et al., 2012; Holzapfel et al., 2022):

- How does bringing our whole selves, inviting and valuing everyone's contributions, impact how and what we learn?
- How do we build trust with the angst and discomfort that arise in interactive environments?
- How do we cultivate environments conducive to open, honest, and inclusive discussions?
- How can creativity influence science or optimize and innovate education and research?

From the experience created together over our coffee chats, conferences (Martinez et al., 2023) and last year's ISLS workshop (Sealfon et al., 2023), we invite the Learning Sciences community to collaborate to examine the following:

- How can we study the "intangible" values of conferences, communities, and co-creating something together?
- What does it mean to be participants in what we are studying? Can we study what we have not experienced?
- What does it mean to transform the metrics we use to be inclusive?

We will facilitate daily activities throughout the conference. This friendly, interactive space will engage participants with each other about what they are learning and experiencing through the rest of the conference. We



offer an activity on each conference day that reflects the conference theme *Learning as a cornerstone of healing, resilience, and community*. We invite participants to approach the three sub-themes of *healing, resilience, and community* in creative, playful, and collaborative ways. Activities may include collective drawings, collages, games, structures, and bulletin boards. The final activity will include a synthesis and debrief of what we will have built together over the previous days. The result is a collaborative work of art that is unique and could only be created through the joint design of many different voices with different perspectives. Using this playful and creative approach, the conference and participants' experiences can be reflected on more effectively.

Expected outcomes for participants include:

- Experience and articulate the relationship of play and improvisation to cultivating an inclusive collective experience.
- Share and explore highlights of what each other is learning throughout the conference.
- Reflect on day-to-day interactions and how cultivating developmental ensembles impacts our teaching and research.
- Manifest understanding of new ideas through playful, embodied, and tangible experiences.
- Get to know other conference participants with similar interests and focuses.
- Gain a preliminary insight into the work of Cultivating Ensembles.

Note that this is not a traditional workshop, but rather an experience that builds throughout the ISLS conference. By inviting participants to experience a new form of learning environment, we create the conditions for additional research questions, partnerships, and discoveries to emerge. We invite participants to continue building with us after the conference, for example through coffee chats hosted by Cultivating Ensembles throughout the year and the upcoming 2025 Cultivating Ensembles conference.

References

Hadzigeorgiou, Y., Fokialis, P., & Kabouropoulou, M. (2012). Thinking about Creativity in Science Education. *Creative Education*, 03(05), 603–611. <https://doi.org/10.4236/ce.2012.35089>

Holmes, R. M. (2022). Cultivating Ensembles: A Relational Reflection on Creating Cultural Transformation with New Performances of Science. In V. Appler & M. Conti (Eds.). *Identity, Culture, and the Science Performance: From the Lab to the Streets* (pp. 54–71). London: Methuen Drama. <http://dx.doi.org/10.5040/9781350234109.0010>

Holzapfel, M. A., Jaggy, A.-K., & Brückmann, M. (2022). Creativity in German Science Education in Elementary Schools: Preservice Teachers' Perspective on Whether It Is Essential, Possible or Completely Unnecessary. *Creative Education*, 13(04), 1421–1438. <https://doi.org/10.4236/ce.2022.134087>

Holzman, L. (2016). *Vygotsky at Work and Play* (2nd ed.). Routledge. <https://doi.org/10.4324/9781315676081>

Jaworski, B. (2006). Theory and practice in mathematics teaching development: critical inquiry as a mode of learning in teaching. *Journal of Mathematics Teacher Education* (2006) 9:187–211

Knudsen and Shechtman, (2011). Bringing out the Playful Side of Mathematics: Using Methods From Improvisational Theater in Professional Development for Urban Middle School Math Teachers. In *Play and Performance*, Play and Culture Series Vol.11

Lemke, J. (2001). "Articulating Communities: Sociocultural Perspectives on Science Education." *Journal of Research on Science Teaching* 38 (3): 296-316. 2001.

Lobman, C. (2010). Creating of developmental moments: Teaching and learning as creative activities. In C. Connery, V. John-Steiner, and A. Marjanovic-Shane (Eds.), *Dancing with the Muses: A cultural-historical activity theory (CHAT) approach to play, meaning-making creativity*. New York: Peter Lang.

Martinez, J. E. (2011). A performative approach to teaching learning and technology, Sense Publishers, Rotterdam, Netherlands.

Martinez, J. E. Natalizio, B. J., and Ali, O. H. Eds. (2023). *Cultivating Ensembles Exploring Across STE{A}M: 2022 Conference Proceedings*. Lloyd International Honors College, The University of North Carolina at Greensboro. <https://honorscollege.uncg.edu/wp-content/uploads/2023/12/Cultivating-Ensembles-Conference-Proceedings.pdf>

Sawyer, R. K. (2004). Creative teaching: Collaborative discussion as disciplined improvisation. *Educational Researcher* , 33 (2), 12–20.

Sealfon, C. D., Gross, N., Raman, P., Holzapfel, M., Borinskaya, S., Natalizio, B. J. & Holmes, R. M. (2023). Cultivating Ensembles in Education and Research at ISLS. In Slotta, J. D. & Charles, E. S. (Eds.), *General Proceedings of the 3rd Annual Meeting of the International Society of the Learning Sciences 2023* (pp. 103-104). Montreal, Canada: International Society of the Learning Sciences.

Schon, D. (1983). *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.



A.I. Augmented Learning for All: Challenges and Opportunities, A View from the Five National AI Institutes

Jinjun Xiong, University at Buffalo, jinjun@buffalo.edu

James Lester, North Carolina State University, lester@ncsu.edu

Jonathan Rowe, North Carolina State University, jprowe@ncsu.edu

H. Chad Lane, University of Illinois, Urbana-Champaign, hclane@illinois.edu

Jeremy Roschelle, Executive Director, Digital Promise, jroschelle@digitalpromise.org

Ashok Goel, Georgia Institute of Technology, goel@cc.gatech.edu

Peter Foltz, University of Colorado, Boulder, peter.foltz@colorado.edu

Abstract: As Artificial Intelligence (AI) becomes increasingly powerful, it is imperative for the general public to learn more about AI and how it can be utilized to address the society's daily challenges. The National AI Institutes represent a cornerstone of the U.S. government's commitment to fostering long-term fundamental research in AI. This workshop will introduce the National AI Institutes program to the Learning Sciences community, and, in particular, will focus on five of such AI Institutes related to the learning science community, i.e., the National AI Institute for Adult Learning and Online Education (AI-ALOE), the National AI Institute for Engaged Learning (EngageAI), the National AI Institute for Student-AI Teaming (iSAT), the National AI Institute for Exceptional Education (AI4ExceptionalEd), and the National AI Institute for Inclusive Intelligent Technologies for Education (INVITE). The objectives are to introduce to the learning sciences community about the various education and learning related use cases being addressed by these AI Institutes, their AI research activities, the current status of AI advancement and limitations, and more importantly, how the learning sciences community can engage with these AI Institutes to shape their research programs to more strongly align with ongoing and emerging research in the field. Key research leaders from the AI Institutes will be invited to speak at the workshop along with other key players.

Introduction

The world of Artificial Intelligence (AI) has seen a significant leap recently in its powerful capabilities, and its applications are no longer science-fiction dreams, but are starting to revolutionize a wide range of industries: agriculture, communications, healthcare, transportation, and learning science and education.

As AI is changing our society's daily lives and giving rise to new capabilities, there still exist a range of challenges, including both technological challenges and societal challenges. For example, much of today's AI technologies rely on the access to large volumes of data, advanced computational infrastructure, and talented researchers and scientists. Yet the AI technologies are still functioning like a black box without much explainability, exhibiting seemingly inherent biases, suffering from issues of reproducibility and generalizability. All of those complexities further prevented the general public from accessing and understanding such powerful yet impactful technologies, which engender fears, mistrust, and sometimes rejection of the adoption of AI to solve societal challenges.

To address these challenges, Congress passed the National AI Initiative Act of 2020 that directed the National Science Foundation (NSF) to work with other federal agencies and stakeholders to create a roadmap for keeping America's leadership in AI while taking advantage of AI for societal benefits. Out of those efforts, NSF launched the *National Artificial Intelligence Research Institutes* program, which now consists of 25 AI institutes that connect over 500 funded and collaborative institutions across the U.S. and around the world. Although the 25 AI Institutes cover different aspects of AI research, five are dedicated to topics of education, learning, human-AI interactions and collaboration. This signifies the importance of learning and education to our society, and the focused investment from federal governments to advance both AI and learning sciences.

Goals

The main goals of this proposed workshop are to introduce the education and learning science community to the five National AI Institutes, their main research focus, research activities, and more importantly, a common set of research challenges resulting from their respective research topics and the advancement made by respective Institutes' researchers. The goals are to engage the large learning sciences community to help guide and shape the priorities of their research efforts. Below is a high-level introduction of the five Institutes.



- *The National AI Institute for Adult Learning and Online Education (AI-ALOE)* develops novel AI assistants for learning and teaching to enhance the proficiency of adult reskilling and upskilling, and thereby transform workforce development. The AI assistants address known problems in online education (lack of cognitive engagement, teaching presence, and social interaction) as well as personalize adult learning at scale. AI-ALOE also develops new AI models and techniques for self-directed learning, data visualization, self-explanation, machine teaching, and theory of mind to make the AI assistants usable, learnable, teachable, and scalable. In addition, AI-ALOE is developing a unified technology and data architecture for deploying and evaluating AI assistants, collecting and analyzing data, and personalizing learning at scale. The Institute is led by Georgia Institute of Technology and includes partners from academia (Georgia State University, Harvard University, Technical College System of Georgia, University of North Carolina at Greensboro, Vanderbilt University), industry (Accenture, Boeing, IBM, Wiley), and non-profit organizations (1EdTech).
- *The National AI Institute for Engaged Learning (EngageAI)* is headquartered at North Carolina State University with the University of North Carolina at Chapel Hill, Indiana University, Vanderbilt University, and Digital Promise as lead partners. The Institute promises to harness the power of AI to revolutionize K-12 STEM education. The Institute's cutting-edge learning environment technologies will create captivating STEM learning experiences featuring AI-generated narratives with dynamic plots, including interactive science problem-solving scenarios, characters, and dialogues, powered by advances in adaptive collaborative learning and multimodal learning analytics. The Institute's work drives foundational AI breakthroughs in natural language processing, computer vision and machine learning tailored to specific educational settings. Ultimately, the Institute seeks to empower science educators by providing curriculum design support and innovative classroom practices that meet the needs of diverse students.
- *The National AI Institute for Student-AI Teaming (iSAT)* is led by the University of Colorado Boulder, and addresses a fundamental question, i.e., how can we foster effective, equitable and engaging learning experiences for all students? The iSAT team is reimagining the role of AI in education as social and collaborative partners (AI Partners) supporting teachers and students to transform classrooms into knowledge-building communities. These communities are designed to promote deep reasoning and knowledge sharing as students collaboratively work to solve complex challenges that are authentic to their interests and societal needs. AI Partners help facilitate small group discussions, aiding students in constructing their own understanding and helping them develop their collaboration skills. They are socially sensitive and can communicate naturally by understanding students' speech, facial expressions, eye gaze and gestures while avoiding the pitfalls of bias and inequity. They also prioritize the trust and comfort of students by avoiding behaviors that might be perceived as surveillance. Critically, AI Partners are not replacing teachers, but are co-designed in collaboration with educators to complement and augment what teachers do best: inspire, teach and nurture students.
- *The National AI Institute for Exceptional Education (AI4ExceptionalEd)* is led by the University at Buffalo and aims to advance artificial intelligence to help speech language pathologists (SLP) practice at their full potential, ensuring no child in need of speech and language services is left behind. Currently, nearly 3.4 million children served under the Individuals with Disabilities Education Act require speech and language services. These children face communication challenges that place them at risk for suboptimal social-emotional and academic outcomes. An alarming shortage of SLPs, combined with delays in identification of needs and unmet services during the COVID-19 pandemic, has likely exacerbated this gap. AI4ExceptionalEd aims to provide SLPs with time-saving tools and insights, allowing them to deliver tailored interventions to children during a fundamental period of growth. This approach mitigates the risk of them falling further behind in their academic and social development. The institute will develop AI technologies complemented by human expertise to inform two innovative solutions: the AI Screener and the AI Orchestrator. These solutions will not only enable the scaling of SLPs' expertise but also provide culturally sensitive universal screening and ability-based intervention. Ultimately, this investment in youth will create a pathway for long-term economic impact as they grow and contribute to the workforce.
- *The National AI Institute for Inclusive Intelligent Technologies for Education (INVITE)* is led by University of Illinois Urbana-Champaign, driven by a fundamental question, i.e., how can AI be leveraged to help achieve education for all? Just as exceptional educators adapt to the individual needs, behaviors and development of diverse learners, INVITE envisions technologies in school that are similarly adaptive. To realize this vision, INVITE is committed to developing AI tools and approaches



that directly address the Education for All initiative. The institute will deliver a new generation of tools that will be radically more responsive to the needs of individual learners and educators. INVITE technologies seek to address key skills and underlying beliefs that are essential for successful learning, all while empowering teachers and families to support children in more nuanced and meaningful ways. INVITE aims to foster three pivotal skills crucial for effective learning: persistence, academic resilience and collaboration. INVITE's use-inspired research focuses on how children learn to become effective collaborators, persist through challenging tasks and bounce back from struggle during learning. To accomplish this, INVITE teams will engage in research and outreach activities in partnership with the INVITE K-12 partner network to reach a community of learners of almost 96,000 students across 24 school districts and nonprofits across eight states.

Formats and agenda

Below is our proposed tentative workshop agenda. We will invite NSF and IES program officers to kick off the workshop with an introduction of the AI Institute Program. We will also invite two keynote speakers to talk about the key challenges and opportunities in AI and learning sciences, respectively. Five leaders from the five AI Institutes will be invited to introduce their respective Institutes' research programs. From those discussions, it will become evident that there are a set of common research themes and challenges facing those AI Institutes, albeit each with a different focus area (such as learning environment design, formative assessments, adaptive scaffolding, multimodality analysis, and AI ethics).

In the interests of time, the remaining of the workshop will focus on three top most challenging research topics that face almost all of our Institute, i.e., (1) Multimodality understanding of a learning scenario, (2) Advancement of Natural Language Understanding in the midst of Large Language Models, and (3) Automatic Speech Translation for Children. We will deep dive into those three topics, discuss their use cases from the respective AI Institutes, and demonstrate what kind of AI advancement we have made so far. But more importantly, we hope that, through these focused deep dives, we can illustrate the gaps of existing AI advancement and what are promising ways to move forward.

We will leave ample time for social interactions among AI researchers (from the five AI Institutes for example) and learning science people who attend the ISLS conference. The workshop will end with an hour-long session featuring key demos from the five AI Institutes on how AI can be used to help the learning science community. Feedback and comments will be collected.

Table 1
Tentative Workshop Agenda

Time	Title	Speakers
9:00 – 9:30	Intro to AI Institute Program	NSF/IES Program Officers
9:30 – 10:30	Overview of the Five National AI Institutes	Institute Representatives
10:30 – 11:00	Coffee Break	
11:00 – 12:00	Demos and Discussions	All
12:00 – 1:00	Lunch Break	Social Interactions
1:00 – 1:45	Interactive session: Multimodality Understanding for a Real Learning Scenario	Moderators + All
1:45 - 2:30	Panel – Connecting Learning Science Careers and AI	Moderator + Panelists
2:30 – 3:00	Coffee Break	
3:00 – 3:45	Interactive session: Advancement of Natural Language Understanding in the midst of Large Language Models	Moderator + All
3:45 – 4:30	Interactive session: Automatic Speech Translation for Children	Moderator + All
4:30 – 5:00	Closing Discussion	All

Organizers

The workshop will be organized by key leaders from the five National AI Institutes, including:

Dr. Jinjun Xiong, who is the Scientific Director for the AI4ExceptionalEd Institute (National AI Institute for Exceptional Education). He is also the Empire Innovation Professor with the Department of Computer Science and Engineering, University at Buffalo. Dr. Xiong's research interests are on across-stack AI systems research, including AI applications, algorithms, tooling and computer architectures. Many of his research results have been adopted in IBM's products and tools. He has published more than 160 peer-reviewed papers in top AI conferences and systems conferences. His publication won 8 Best Paper Awards and 9 Nominations for Best Paper Awards. He also won top awards from various international competitions, including the championship award for the IEEE GraphChallenge on accelerating sparse neural networks in 2020, and the First Place Awards



for the 2019 DAC Systems Design Contest on designing an object detection DNNs for edge FPGA and GPU devices, respectively.

Dr. James Lester is the Director of the National Science Foundation AI Institute for Engaged Learning. He is also the Goodnight Distinguished University Professor in Artificial Intelligence and Machine Learning in the Department of Computer Science at North Carolina State University. His research centers on transforming education with artificial intelligence. His current work ranges from AI-driven narrative-centered learning environments and virtual agents for learning to multimodal learning analytics and sketch-based learning environments. He is the recipient of a National Science Foundation CAREER Award, four Best Paper Awards, and the International Federation for Autonomous Agents and Multiagent Systems Influential Paper Award. He has served as Editor-in-Chief of the International Journal of Artificial Intelligence in Education. He is a Fellow of the Association for the Advancement of Artificial Intelligence (AAAI).

Dr. Jonathan Rowe is the Managing Director for the EngageAI Institute (NSF AI Institute for Engaged Learning) and a Senior Research Scientist in the Center for Educational Informatics at North Carolina State University. He received Ph.D. and M.S. degrees in Computer Science from North Carolina State University and his B.S. degree in Computer Science from Lafayette College. Dr. Rowe's research focuses on artificial intelligence in adaptive learning technologies, with an emphasis on game-based learning, interactive narrative generation, intelligent tutoring systems, multimodal learning analytics, affective computing, and user modeling. He has served as Program Chair and General Chair for the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment, and he currently serves as an associate editor for the *International Journal of Artificial Intelligence in Education*.

Dr. H. Chad Lane is an Associate Professor of Educational Psychology and Computer Science at the University of Illinois, Urbana-Champaign and serves as Director of the INVITE NSF AI Institute focused on the development of inclusive AI-based educational technologies. Chad's research focuses on the design, use, and impacts of intelligent technologies for informal and formal STEM learning. With over 120 publications, his work involves blending techniques from the entertainment industry (that foster engagement) with those from artificial intelligence and intelligent tutoring systems (that promote learning), as well as running studies to better understand whether and how the resulting learning experiences impact learners. His recent work investigates the use of video games (like Minecraft) to promote interest in science, with an emphasis on learners who are underrepresented and underserved in STEM. His PhD is in Computer Science from the University of Pittsburgh (2004), and prior to joining UIUC, he spent ten years as a research scientist and Director of Learning Sciences Research at the USC Institute for Creative Technologies.

Dr. Jeremy Roschelle is a Fellow of the International Society of the Learning Sciences and serves as Executive Director of Learning Sciences Research at Digital Promise. He is a co-PI of AI Engage where he leads the Nexus, which forges connections among people inside and outside the Institute, including researchers, practitioners, and industry. Jeremy's research interests include collaborative learning, mathematics learning with technology, and leading research hubs (a.k.a. knowledge networks). Oddly enough, he hung around the MIT AI lab circa 1985, but thinking nothing much of practical use would come of all this AI-stuff, he forged a career instead in the learning sciences.

Dr. Ashok Goel is a Professor of Computer Science and Human-Centered Computing in the School of Interactive Computing at Georgia Institute of Technology, and the Chief Scientist with Georgia Tech's Center for 21st Century Universities. For almost forty years, he has conducted research into cognitive systems at the intersection of artificial intelligence and cognitive science with a focus on computational design and creativity. For almost two decades, much of Ashok's research has increasingly focused on AI in education and education in AI. He is a Fellow of AAAI and the Cognitive Science Society, an Editor Emeritus of AAAI's AI Magazine, and a recipient of AAAI's Outstanding AI Educator Award and Distinguished Service Award. Ashok is the PI and Executive Director of NSF's National AI Institute for Adult Learning and Online Education (aialoe.org).

Dr. Peter Foltz is Research Professor in the Institute of Cognitive Science at the University of Colorado, Boulder and Executive Director of the NSF Institute for Student-AI Teaming. His work covers machine learning and natural language processing for educational and clinical assessments, large-scale data analytics, cognitive skills in reading and writing, team collaboration, and 21st Century skills learning. Much of his work has focused on AI-based approaches for automatically analyzing the meaning of language through writing and speaking. He has developed and implemented these approaches in both academia and industry and they are used for assessing abilities, for providing feedback, and for understanding underlying cognitive mechanisms in the brain. The methods he has pioneered are used by millions of people annually to improve achievement, expand student access, and make learning materials more affordable.



Network of Academic Programs in the Learning Sciences: Reigniting NAPLeS

Marcela Borge, The Pennsylvania State University, USA, mborge@psu.edu

Daniel Hickey, Indiana University, USA, dthickey@indiana.edu

Freydis Vogel, Universität Hamburg, Germany, freydis.vogel@uni-hamburg.de

Abstract: The Network of Academic Programs in the Learning Sciences (NAPLeS) was initiated more than a decade ago to connect academic learning sciences programs at universities across the globe. Over 60 programs have joined the network so far and have contributed to various initiatives and the collection of resources. We invite faculty affiliated with a current or prospective learning sciences program to participate in discussing and planning various formats of exchange to further build links between the different programs and shape a joint identity. Formats of exchange include but are not limited to the collection of syllabi and resources on the website, planning joint seminars, and exchanges between students and faculty in different programs. With this workshop, the successful network should be reignited and maintained as a valuable source for academic programs in the learning sciences.

Organizing team

This workshop is organized by three ISLS members with a long commitment to academic programs in the learning sciences and a shared vision of an ongoing network of academic programs that support international collaboration and exchange. **Marcela Borge** is an associate professor in the Penn State Learning, Design, and Technology program. She has been helping with the organization and maintenance of education committee initiatives and the Network of Academic Programs in the Learning Sciences since 2014. Dr. Borge has been a program co-chair for two CSCL conferences and led multiple early-career and mid-career workshops. Dr. Borge was also elected to serve as a CSCL community member. **Daniel Hickey** is a Professor in the IU learning sciences program. Dr. Hickey has previously served as a member of the ISLS Education Committee and has been a member of multiple ICLS program committees and was ISLS conference co-chair in 2006. Dr. Hickey was active in the initial NAPLeS efforts and is currently involved in international collaborations with Taiwan, China, and Germany and is currently working towards a continuing multinational graduate seminar entitled *Emerging International Perspectives and Challenges in the Learning Sciences*. **Freydis Vogel** is a Professor in the Department of General, Intercultural, and International Comparative Education and the Department of Educational Psychology. Doctor Vogel has been involved with organizing and maintaining the Network of Academic Programs in the learning sciences for more than a decade. The organizing team successfully conducted three workshops around the topic at past ISLS and CSCL conferences (Vogel et al., 2014, 2017, 2019).

Theoretical background and relevance to field and conference

Historically, the learning sciences evolved around various disciplines such as cognitive science, sociology education, psychology or computer science (Hoadley, 2018). Thus, teaching in a learning sciences program involves students in an interdisciplinary field with varying foci and content. When exploring the range of available academic learning sciences programs, it becomes apparent that although there is an overlapping understanding of various theories and methods, programs focus on different areas of the Learning Sciences (Sommerhoff et al., 2018). This range of what learning sciences programs can look like exists, because, as a field, the learning sciences aims to integrate diverse backgrounds and multiple perspectives towards a common goal: understanding learning, learners, and the design of learning contexts in theoretically and scientifically informed ways that prioritize ecological validity (Fischer et al., 2023).

Some learning sciences programs are core programs within dedicated learning sciences institutes, others form a specialization within a discipline such as education or the programs combine courses from many related disciplines such as psychology, computer science, or information sciences (Sommerhoff et al., 2018). Many other fields share commonalities with the learning sciences but lack the scientific background the learning sciences community has built since it started decades ago (Lee, 2023). However, there is still room for improvement, as our community is often criticized as insular and not actively participating in the design of technologies, policies, or public interest campaigns necessary to make significant broader impacts (Kolodner, 2023). We must also continue to strengthen our own community to improve how we educate our future scholars. Thus, it is crucial to



build links between the different programs, shaping a joint identity while emphasizing the specialty and strengths of each individual program.

Towards this aim, the Network of Academic Programs in the Learning Sciences (NAPLeS) was founded twelve years ago by core learning sciences programs at about a dozen universities. NAPLeS has continued to grow ever since, with more than 30 universities now making up its membership. This network aims to offer a platform for leaders and faculty in learning sciences programs to exchange resources and support each other in their endeavor to establish their program at their specific place (ISLS, n.d.). The network efforts were paused in 2020 amidst pandemic disruptions and travel restrictions. However, there is still an ongoing interest in the learning sciences community. There is a particular need for newly established or planned programs to be part of the network and engage in exchange activities. Each year, several programs apply to join the network. Therefore, this workshop aims to reignite the network, welcome new members, update existing membership information, brainstorm new initiatives, and initiate exchange activities throughout the year.

Outline of planned activities

The goal of this workshop is to reignite and maintain the network of academic programs in the learning sciences. For this, faculty affiliated with a current or prospective learning sciences program are invited to participate in discussing and planning various formats of exchange: exchanging syllabi, joint seminars, updating online content, student/faculty exchange, and new initiatives. During the half-day workshop, the following activities are scheduled and will include breaks for coffee and refreshments.

1. Introduction to NAPLeS and introduction of participating programs (30 minutes): The workshop organizers will introduce NAPLeS and the purpose of the network. As participants from already established and newly founded programs will come together, each participating program will shortly be introduced to inquire the different focus and background of each program.
2. Introduction of key topics in the workshop (30 minutes): *Marcela Borge* will introduce the diverse resources NAPLeS gathered over the last twelve years, which are available on the ISLS NAPLeS webpages. This includes the syllabi collection, video resources and recordings from past webinar series. *Freydis Vogel* will introduce the diverse initiatives NAPLeS conducted and planned in the past. This includes webinar series and the facilitation of student and faculty exchange between programs. *Daniel Hickey* will sketch out his current initiative of a multinational graduate seminar entitled *Emerging International Perspectives and Challenges in the Learning Sciences*. This may serve as a blueprint for further multinational seminars in the future.
3. Plenum discussion and decision for a topic of interest (30 minutes): Workshop participants will discuss the benefits and drawbacks of different initiatives. As the collection of resources needs continuous maintenance and input from the community, participants will discuss which resources should be kept and expanded, which may be omitted and what needs to be added to support learning sciences programs. Based on this discussion, the organizers will create focus groups for different topics of interest so participants can have agency in crafting the future direction of NAPLeS.
4. Work in focus groups on a the topic of interest (120 minutes): Participants will break-out into their focus groups to work intensively on the developing possibilities to strengthen the exchange between learning sciences programs in relation to each focus group topic. One of the workshop organizers will facilitate the work in each focus group.
5. Consolidation (30 minutes): Each focus group presents an action plan for post-processing activities and how the set goals should be achieved. The whole group will discuss possible links between different plans (e.g. planning of a joint seminar could add a syllabus for this seminar to the collection)

Expected outcomes and contributions

The expected outcomes of the workshop are:

- Improving the supportive resources NAPLeS offers to all Learning Sciences programs on the NAPLeS webpage. This particularly includes the syllabi collection, which needs updating to represent the more diverse range of topics that currently make up the Learning Science.
- Successfully conducting joint seminars with participants of two or more Learning Sciences programs, preferably including programs from multiple continents.



- Getting Learning Sciences programs of NAPLeS involved in contributing to various resources and initiatives that have been identified to be helpful during the workshop discussions.

References

Fischer, F., Sommerhoff, D., & Keune, A. (2023). Perspectives on learning from the learning sciences. In R. J. Tierney, F. Rizvi, & K. Ercikan (Hrsg.), *International Encyclopedia of Education* (Fourth Edition) (S. 44–56). Elsevier. <https://doi.org/10.1016/B978-0-12-818630-5.14007-2>

Hoadley, C. (2018). A short history of the learning sciences. In F. Fischer, C. Hmelo-Silver, S. R. Goldman, & P. Reimann (eds.) *International Handbook of The learning sciences* (pp. 11-23). Routledge. <https://doi.org/10.4324/9781315617572>

ISLS (n.d.). *NAPLeS*. International Society of the Learning Sciences, retrieved December 10, 2023, from <https://www.isls.org/naples/>

Kolodner, J. L. (2023). Learning engineering: What it is, why I'm involved, and why I think more of you should be. *Journal of the Learning Sciences*, 32(2), 305-323. <https://doi.org/10.1080/10508406.2023.2190717>

Lee, V. R. (2023). Learning sciences and learning engineering: A natural or artificial distinction? *Journal of the learning sciences*, 32(2), 288-304. <https://doi.org/10.1080/10508406.2022.2100705>

Sommerhoff, D., Szameitat, A., Vogel, F., Chernikova, O., Loderer, K., & Fischer, F., (2018) What Do We Teach When We Teach the learning sciences? A Document Analysis of 75 Graduate Programs. *Journal of the learning sciences*, 27(2), 319-351. <https://doi.org/10.1080/10508406.2018.1440353>

Vogel, F., Borge, M., Damsa, C., Davis, P., Eberle, J., Fischer, F., & Sommerhoff, D. (2019). Creating common ground for teaching designs in learning sciences programs: Building on CSCL research and practice. In: K. Lund, G. Niccolai, E. Lavoué, C. Hmelo-Silver, G. Gweon, and M. Baker (Eds.). *A Wide Lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings, 13th International Conference on Computer Supported Collaborative Learning (CSCL) 2019, Volume 2*. (p.1043). Lyon, France: International Society of the learning sciences.

Vogel, F., Fischer, F., & Sommerhoff, D. (2014). NAPLeS: Networked Learning in the learning sciences. In J. L. Polman, E. A. Kyza, D. K. O'Neill, I. Tabak, W. R. Penuel, A. S. Jurow, K. O'Connor, T. Lee, & L D'Amico (Eds.), *Learning and Becoming in Practice: The International Conference of the learning sciences (ICLS) 2014*, Volume 3. (pp. 1704-1708). Boulder, CO: International Society of the learning sciences.

Vogel, F., Fischer, F., & Sommerhoff, D. (2017). Reflections and discussions about NAPLeS learning resources for the learning sciences. In: B. K. Smith, M. Borge, E. Mercier, & K. Y. Linn (Eds.). *Making a Difference: Prioritizing Equity and Access in CSCL*, 12th International Conference on Computer-Supported Collaborative Learning (CSCL) 2017, Volume 1. (pp. 922-923) Philadelphia, PA: International Society of the learning sciences.



Educating for Ecological Caring on a Damaged Planet: Designing and Building Refugia with/for More-than-humans

Kelsie Fowler, University of Washington Seattle, knp7@uw.edu

Marijke Hecht, The Ohio of University, hecht.102@osu.edu

Philip Bell, University of Washington Seattle, pbell@uw.edu

Anastasia Sanchez, University of Washington Seattle, sapient@uw.edu

Kaleb Germinaro, University of Illinois at Chicago, kaleb@uic.edu

Chris Jadallah, University of California Los Angeles, cjadallah@g.ucla.edu

Nancy Price, University of Washington Seattle, pricenj@uw.edu

Abstract: We are living in an age of climate and environmental crisis. It is having disproportionate effects with those who have caused it are not those experiencing the worst effects. Also, the material resources available to respond to the poly-crises unfolding are also unevenly distributed (Taiwo, 2022). In keeping with the ICLS theme, this is a time that calls for engaging community deeply in practices of healing and resilience—including practices that disrupt human supremacy in climate response and that centers caring practices for multispecies justice. In this workshop, multiple research groups working in this space of ecological caring will showcase theory, participatory methods, and research findings to help participants build their capacity to engage others in similar work in their contexts.

Introduction

This age of acute climate crisis and environmental degradation brings with it disproportionate impacts on some human and more-than-human communities more than others. Relatedly, there is a growing awareness that we need to broadly disrupt the intersecting logics of white supremacy, settler-colonialism, anthropocentrism, consumption, and extraction in our human-nature relations. Our damaged planet necessitates that we bring these dominant societal frames of ecological and more-than-human genocides into sharp, troubled, focus. Doing so beckons us to slow down (Stengers, 2018) and mind (Griffiths & Murray, 2017) how we shift human thinking, learning, and behavior towards caring for multispecies communities in the face of careless, intentional violence. It is only through these moments of reflexivity that we can create counterweights to the deluge of damage, and engage in worldbuilding toward ecological thriving and abundant futures (Tzou, Bang, & Bricker, 2021). Given the conference theme of learning as a cornerstone of healing, resilience, and community, we propose this workshop as an invitation to join in this “troubling” (Haraway, 2016) and explore how engaging with the literacies of Land (Styres, 2018) and centering multispecies ethics (Puig de la Bellacasa, 2017) can foster onto-epistemic transformations in ourselves and our work as learning scientists.

Informed by six varied projects, all situated uniquely across the United States and Mexico, our workshop will offer a promising map for learning, teaching, research, and living as humans during this precarious time. By intentionally drawing different worlding projects together, we offer distinct frameworks and a carefully curated set of tools, including instructional materials, designed to cultivate situated collective care. We use “worlding” to mean projects that endeavor to bear more just and sustainable futures (Mitchell & Chaudhury, 2020). The heterogeneous approach to the workshop leans into multilogics (Higgins & Tolbert, 2018) and the speculative logics associated with collective flourishing, survivance, and continuance (Puig de la Bellacasa, 2017) in a refusal of the moral universalism promulgated through colonial logics (Grosfoguel, 2013). Additionally, our theoretical frameworks, storytelling, space making practices, and interpretive discourse practices will challenge participants to think across time, geographies, and scales of individuality and collective-being to center the knowledge, interests, worldsense, and futurities associated with Black, Brown, and Indigenous people of the global majority (Roane et al., 2022). Some of the constructs and resources that will be elevated include design principles of citizen science and other forms of socio-ecological activism, “ecological mutations” of human-nature relationships and thick caring, tools and definitions for better attending to our interior landscapes, pedagogies for developing students’ critical geographies through formal education, expanding the role of education and learning as a care praxis, and guidance for developing our own (and others’) protector identities for a living and flourishing world.

Our goals in bringing this work together are to:

1. Unpack, apply, and compare diverse theoretical frameworks for more deeply understanding, interpreting, and moving through this damaged planet by cultivating thick care that sits in opposition to white settler logics, including but not limited to posthumanism, new materialism,



Black ecologies, and Indigenous ontoepistemologies (e.g., Bang & Marin, 2015; Barad, 2007; Haraway, 2016; Roane et al., 2022).

2. Learn how to slow down, offer our full attention to the world around us and design learning and activism so it attends to the exterior and interior realities of living in this broken world and sustains our response-abilities (Haraway, 2016; Higgins & Tolbert, 2018) to the more-than-human world.
3. Form a community of scholars at ISLS dedicated to strengthening the bonds of human-nature relationality (Bang & Marin, 2015) and responsibilities to the more-than-human world, including LandAirWaterStars (Sanchez, 2023).

Description of workshop

This full-day workshop is organized around three outdoor strolls that mirror the practices and goals evolving from our diverse projects. Each unique stroll will provide time to deeply engage in a different dimension of attending to our human-nature relations and socio-ecological responsibilities (Tzou, Bang, & Bricker, 2021). Tools, frameworks, new pedagogies, and reflexive protocols that have come from our individual work will be used to support this multi-dimensional thinking and give us products to reason around/with. To conclude our time together, participants will collaborate in ethico-ontoepistemological crafting (Barad, 2007) to consider how we, as learning scientists, have a response-ability for troubling understanding of the damaged planet—and engaging as a community in critical and restorative methodologies centered on thick care. Our hope is that from this design time will emerge methodological suggestions, protocols, and designs to carry with us out into the world.

The workshop will aim to explore the following questions:

- Where do we see, interpret, or find evidence of caring for the more-than-human world? How does one's positionality and relation-to-place place inform ethical forms of caring (e.g., in support of Indigenous sovereignty)? Where is socio-ecological care absent?
- Human caring is often contentious or reproductive of oppressive violence, and narratives, of human superiority. What forms of socio-ecological caring ought we be most concerned about? Which forms should be centered in education?
- How might slow and deliberate walking in local communities—what we call here “strolls”—become part of the cornerstones of healing, resilience, and community—in support of the theme of the 2024 conference? What tools, theories, narratives, infrastructures, and relationships are needed to carry into our work as educators and learning scientists?

Prerequisites

All participants are welcome and will be asked to do a 45 minute “stroll” near the place that they live, work, and/or study before attending. They will be encouraged to select at least one of the questions above to use as a prompt that they will reflect on during their stroll and then represent through an artifact. This artifact may be something found or crafted. Artifacts and initial reflections on the questions will be shared in the beginning hour of the workshop.

Agenda

Below is a detailed agenda for the workshop, including brief descriptions and rationales of each activity.

Time	Activity	Description and Rationale
9:00	Welcome, Workshop Framing and Participant Sharing of Pre- Work [Everyone]	Following introductions, participants will share the artifacts they prepared as pre-work for the day (see below for more details). Then the presenters will offer grounding theories and considerations to hold throughout the workshop. Finally, brief introductions will be given by each of the presenters and the projects they are carrying into the work for the day.



10:30	Stroll I: Socio-ecological Learning & Troubling “Our Best Efforts” [Chris & Kelsie]	During this first stroll we will begin by getting to know and appreciating local multispecies communities and LandAirWaterStars (Sanchez, 2023) by engaging in small group forms of socio-ecological caring. Throughout the stroll participants will slow to practice Socio-ecological Minding—identifying master narratives and ecological mutations that seeped (or try to) into our efforts. Groups will produce reflexive visual representations of their caring, witnessing, and troubling.
12:00	Lunch	Optional: Participants can opt into joining a community lunch at a local food venue.
1:00	Stroll II: Designing Worlds In Community & Attending to Exterior and Interior Landscapes [Kaleb & Marijke]	This activity will shift the workshop towards considering how to design Socio-ecological learning activities to connect with larger sociopolitical landscapes of care and reciprocity through more flourishing and consequential forms of community. Central to this work is attending not only to exterior landscapes, but our interior ones as well. Throughout this time participants will explore artifacts and design tools to guide and prompt personal and professional shifts that have been developed through professional development and youth design work.
2:30	Break	
2:40	Stroll III: Engaging Youth & Community as Protectors [Phil, Nancy & Anastasia]	In this last activity, small groups will build on insights from prior strolls. They will apply the concept of the thick present (representing the unfoldings of the last century or so) to inform their art of noticing and consideration of different models of human-land relations (e.g., Land as Property vs. Land as Teacher). Models of human-land relation where socio-ecological caring involves the protection of the living world for just and flourishing purposes will be centered. Groups will consider the kinds of narratives and learning encounters that align with developing those protector identities.
4:00	Refugia Building as Learning Scientists on this Damaged Planet [Everyone]	Drawing our collective learning together, we will respond to our ethico-ontoepistemological Response-abilities (Barad, 2007; Higgins & Tolbert, 2018) and create new protocols for working as learning scientists and sharing our work with the world. The protocols, along with other tools and artifacts from across the workshop will be curated and prepared for display during ISLS for other attendees to learn from/with, add to and reflect upon.



Intended Audience

The workshop is designed for learning scientists, climate change and environmental educators, teacher educators, community leaders, and any other educators or educational researchers who want to build their practice-based understanding and capacity to slow down and deepen their connections with the more-than-human world. As this workshop is a creative space of fugitivity beyond western dominant settler logics (Dietrich, 2016; Cajete, 2000), attendees need to be open to learning outside, in community, and through creative/crafty learning activities.

References

Bang, M., & Marin, A. (2015). Nature–culture constructs in science learning: Human/non-human agency and intentionality. *Journal of Research in Science Teaching*, 52(4), 530-544.

Barad, K. (2007). Meeting the Universe Halfway. Duke University Press.

Cajete, G. (2000). Native Science: Natural Laws of Interdependence. Clear Light Publishers.

Dietrich, R. (2016). Made to move, made of this place. *Amerikastudien/American Studies*, 61(4), 507-525.

Griffiths, M. & Murray, R. (2017). Love and social justice in learning for sustainability. *Ethics and Education*, 12, 39-50.

Grosfoguel, R. (2013). The structure of knowledge in westernised universities: Epistemic racism/sexism and the four genocides/epistemicides. *Human Architecture: Journal of the sociology of self-knowledge*, 1(1), 73-90.

Haraway, D. (2016). Staying with the Trouble: Making Kin in the Chthulucene. Duke University Press.

Higgins, M. & Tolbert, S. (2018). A syllabus for response-able inheritance in science education. *Parallel*, 24(3), 273-294.

Puig de la Bellacasa., M. (2017). Matters of care: Speculative ethics in more than human worlds. Minneapolis: University of Minnesota Press.

Mitchell, A. & Chaudhury, A. (2020). Worlding beyond ‘the’ ‘end’ of ‘the world’: white apocalyptic visions and BIPOC futurisms. *International Relations*, 1-24, 20-24.

Roane, J. T., Femi-Cole, M., Nayak, P., & Tuck, E. (2022). “The seeds of a different world are already alive in the everyday practices of ordinary Black and Indigenous people”: An interview with JT Roane. *Curriculum Inquiry*, 52(2), 129-138.

Sanchez, A. (2023). The social focus framework: Anti-racist and Anti-colonial conscientization, consequence and presencing in science education. In S. Tolbert, M. Wallace, M. Higgins, & J. Bazzul (Eds.) *Reimagining Science Education in the Anthropocene: Volume II*. Cham: Palgrave Macmillan.

Stengers, I. (2017). Another Science is Possible: Manifesto for slow science. Polity.

Styres, (2018).

Tzou, C., Bang, M., & Bricker, L. (2021). Commentary: Designing science instructional materials that contribute to more just, equitable, and culturally thriving learning and teaching in science education. *Journal of Science Teacher Education*, 32(7), 858-864.



Learning {Blank} Science Fiction and Fantasy: Exploring the Relationship between Genre Fiction and the Learning Sciences

Deborah Dutta, Institute of Rural Management Anand, debbiebornfree@gmail.com
Suraj Uttamchandani, Adelphi University, suttamchandani@adelphi.edu

Abstract: Calling all Science Fiction and Fantasy-loving Learning Scientists! Join us for a workshop at ISLS 2024, entitled, “Learning {Blank} Science Fiction and Fantasy: Exploring the relationship between genre fiction & learning sciences.” In this workshop, we will examine potential avenues of overlap for the learning sciences and science fiction and fantasy writing, including some of the moral, aesthetic, cultural, and pedagogical questions raised at this intersection. No prior experience with science fiction and fantasy scholarship is required, but participants should be passionate about the genres, and consumers of it whether in text or other forms of media. The workshop will include opportunities for both face-to-face and online-only participation.

Introduction

In this workshop we will bring together ideas and perspectives on speculative fiction and its potential to support learning, dialogue, and pedagogy aimed at navigating uncertain futures. In the wake of multiple crises populating daily narratives, beyond funds, technology, and political will we desperately need minds skilled at *envisioning* alternate forms of economy, society, and culture. This is crucial because people are increasingly negotiating with dire visions and abstract information, which together can lead to states of helplessness and existential anxiety (Benoit et al., 2022; Crandon et al., 2022). Engaging with the nonlinear causations involved in the forthcoming changes, given their vast spatial and temporal scales, poses a daunting cognitive and cultural challenge. Changing the relationship with dire future scenarios presented in most mainstream discourses (or denied outright) requires actively imagining the kinds of futures that might exist and are desirable for collective wellbeing.

Science Fiction and Fantasy (taken together as SFF) are popular genres of speculative fiction that explore issues of the fantastic, the futuristic, and the alternative with depth. SFF is not easy to define rigidly, but comprise of stories with elements we might deem impossible in the current day—magic, mythical creatures, “second worlds,” faster-than-light space travel, aliens, multiverses, and so on (e.g., Oziewicz, 2017; Walton, 2010). Although there are crucial differences between science fiction and fantasy (e.g., Scalzi, 2005), it makes sense to think about them together (as SFF), as the Hugo Awards group does. SFF is enormously popular, from young adult texts like *The Hunger Games*, to blockbuster movies like *Dune*, to TV programs like *Game of Thrones*. In addition, SFF is useful as a tool to read and write with when engaging in speculative design. Indeed, the intersection of speculative education and racial justice was the topic of a recent special issue of *Journal of the Learning Sciences* co-edited by Mirra and Garcia (2023).

Given the popularity of SFF and its potential to enable the cognitive and affective dimensions associated with future-oriented thinking, it is useful to examine the relationship between this genre and learning sciences phenomena. We title this workshop “Learning {Blank} Science Fiction and Fantasy” to highlight the different ways the learning sciences could interface with SFF: scholars could explore theories of learning through the writing of SFF, young people could explore scientific concepts like biology through reading SFF, minoritized communities could engage in activist future-making inspired by visions of SFF, and people could engage in fan culture around SFF, just to name a few examples. The goal of the workshop is to fill in the {blank} (e.g., “about,” “with,” “through,” “by examining”). However, exploring the epistemic and pedagogical potential of these diverse avenues in learning sciences requires an initial mapping of possibilities. This workshop proposes a gathering of educators and researchers passionate about SFF to invite ideas, resources, and questions to enrich dialogues between learning sciences and genre fiction.

Theoretical background: SFF possibilities and relevance to learning sciences

Educator David Hicks once pointed out that, “If all education is for the future then the future needs to be a more explicit concern at all levels of education” (Hicks, 2004, p. 167). In the wake of the multiple sociocultural, economic, and ecological crises (e.g., pandemic, natural disaster-related power outages, mass incarceration) embedding themselves as new normals in everyday narratives, it is now perhaps even more important to articulate what kind of futures, and whose futures, are being actively made and unmade. Confronting existential challenges such as climate change, economic inequality, and injustice, however, requires a radical break from the habits and



collective modes of thinking that have mediated these issues in the first place. Milkoreit (2016) argues that the failure to engage with systemic issues isn't due to a lack of action, but of imagination. She reflects on how our imagination is largely bound to the systems we live in. We draw ideas from what we know and what already exists in our surroundings. So, thinking of radically different futures that are bound to unfold presents an unprecedented challenge. Engaging with SFF offers generative possibilities to actively adapt and reconfigure familiar perspectives and events into novel situations, and suspend disbelief in favour of "what ifs." As a "mind-stretching force for the creation of the habit of anticipation" (Toffler, 1984, p. 412), imaginary explorations can provide a relatively safe space to inhabit unfamiliar roles and contexts, and can mediate cultural positionings of risk.

The cognitive and affective capacities, and the community and participatory processes, required for such imagination thus merit more attention and research. Learning scientists are well-positioned to lead such research. As we are increasingly faced with unprecedented events and scenarios, the ability to foresee and design a multitude of possibilities and counterfactual narratives is a critical educational goal to pursue. These skills also form a less understood and appreciated part of scientific thinking. Drawing on recent studies spanning cognitive science, philosophy, and psychology, we understand imagination as an embodied process of anticipation, collaboration, and interpretation of reality (Pelaprat & Cole, 2011; Seligman et al, 2016). As an intersubjective activity, it serves as a dynamic action model of the world, thus lending potency to collective imaginaries. As Finn and Wylie (2021) point out, far from being a whimsical ability mysteriously available to select people, imagination is a core cognitive mechanism used to various degrees to function in a given environment, to simulate possible effects of actions, to empathize with others, and to expand the boundaries of knowability. Of course, imagination is bound up in culture, community, and politics (e.g., Thomas, 2019).

SFF as a genre therefore offers many possibilities as avenues for learning sciences-relevant research. We offer here a non-exhaustive list to illustrate the wide variety of paths that learning scientists might explore:

1. The ability to read and interpret the incredibly rich fictional worlds of SFF represents complex and developed worldbuilding skills on the part of the writer but also, Jo Walton (2010) argues, on the part of the reader, who enables this worldbuilding through active participation in the text.
2. SFF offers opportunities to think critically about political and social arrangements in the pursuit of equity. For example, a foundational critical race theory text *The Space Traders* by Derrick Bell (1992) is, in practice, a SFF short story. In another example, literacy scholar Ebony Elizabeth Thomas (2019) argues that SFF can also be a site to think critically about race through examinations of "the dark fantastic."
3. As implied by the name SFF, SFF necessarily engages STEM concepts, and often provokes novel ways of thinking about concepts such as algorithms, technologies, energy and power, ecosystems, language, and cognition. Ideas of communication, for instance, have been creatively and critically examined in Ted Chiang's *Story of Your Life* through attempted dialogues with alien species, and in Richard Powers' *Bewilderment* through a neural network programme connecting a child with his deceased mother's emotional states. These stories examine the ethical entanglements underlying the use of the technologies described.
4. The use of story and narrative, including SFF story, can be useful for designing learning scenarios (e.g., Wang et al., 2022; Mawasi et al., 2020), such as the game *Alien Rescue* (Liu et al., 2002), and other designs (e.g., the aforementioned *JLS* special issue; Mirra & Garcia, 2023).
5. Interdisciplinary thinking about STEM can be supported by SFF, for example by cross-content lessons that mingle genre writing and science learning (e.g., the *Cities of Light* project by the Arizona State University Center for Science and the Imagination; Eschrich & Miller, 2021).
6. The analysis of SFF texts can be useful for advancing educational theory and philosophy. For example, de Freitas and Truman (2020) discuss issues of "climatic regime and dis/trust in science" (p.2) in Hugo award winner *The Three Body Problem* by foregrounding the book's thrust on tensions between technology, ideology, and culture, and how collective fear and anxiety can propel difficult choices.
7. SFF can provide an opportunity to explore moral questions in "uncharted territories" such as augmented bodies (e.g., *Ghost in the Shell*), planetary collapse (e.g., Diane Cook's *The New Wilderness*), or colonization and resistance (e.g., Robert Jackson Bennet's *City of Stairs* series), including not only ethical but aesthetic/axiological questions associated with the craft of telling such stories (Salessas, 2021).
8. SFF is a space of intense cultural study and anthropological thinking, relevant to sociocultural theory. Since cultural building and representation are central to SFF, reading and writing can explore the cultural impacts of technologies and other cultural shifts, for example, the introduction of fast-flying cars and their impact on the notion of geographic nations in Ada Palmer's *Terra Ignota* series.



9. Crucially, SFF can help us decenter the human, see other perspectives, and re-imagine the relationships between humans and others, such as plants and plant ecologies (e.g., interacting with sentient ecosystem in Jeff Vandermeer's *Annihilation*) non-human animals (e.g., a wolf in Robin Hobb's *Assassin's Quest*); aliens and parasites (e.g., Stephenie Meyer's *The Host*), and geological earth (e.g., N.K. Jemisin's *The Fifth Season*).
10. Diverse cultures influencing fantasy, from mythologies, fairy tales, and oral histories - for example, S.A. Chakraborty's *City of Brass*, Naomi Novik's *Spinning Silver*, or Vandana Singh's *Ambiguity Machines* - provide opportunities to internationalize perspectives on themes relevant to the learning science from SFF (e.g., ways of looking at STEM concepts or ways of thinking about education and learning)
11. Significant work in media studies has suggested that deep human activity and connected learning can take place in fandom cultures (e.g., Jenkins, 2006; Ito et al., 2013).
12. Finally, as evidenced by increasing interest in the sub-genre of *Dark Academia* (e.g., R.F. Kuang's *Babel*), ways of thinking about learning, such as apprenticeship, intensive education, and mentorship, can be examined in SFF texts (e.g., narratives of apprenticeship and training in *Avatar: The Last Airbender*).

More discussion is needed to better categorize, group, taxonomize, hone, and evaluate these affordances of SFF as paths forward in learning sciences literature - such is the goal of the workshop. Taken together, these avenues suggest major modes for learners (and learning scientists) to learn *about* SFF, *with* SFF, and *through* SFF. They surface many learning sciences-relevant research questions with as broad a range as "What role does SFF fandom have in supporting students' understanding of complex STEM concepts?" to "How does reading queer romance (romantic fantasy) together shape LGBTQ+ activists' collaboration and strategy development?" However, this is undoubtedly a broad list. The broadness of the possibilities is the impetus for a workshop in which we bring people together to engage in dialogue about potential research projects that link learning and SFF, working towards a research agenda that can leverage LS concepts and methods to create novel contributions to SFF art and scholarship, as well as reciprocally growing visions of learning through SFF.

Outline of planned activities

We propose a 6-hour workshop design involving three hours of asynchronous and three hours of synchronous work. This design, in contrast to a solely synchronous workshop, helps support inclusive participation across different time zones and communities. The three hours of asynchronous work will be spread across two weeks before the conference: (1) a week of personal reflection (~1 hour) followed by (2) another week of group web annotation of a select set of resources, such as pieces cited in this proposal or other critical essays (e.g., Doctorow, 2018; Onoguwe, 2023; Sklar, 2021) (~2 hours). Finally, (3) we will have a 3-hour synchronous workshop session during the ISLS meeting. During the first week, participants will be invited to read this workshop proposal closely and reflect on their motivation to participate by authoring a short 150-word write-up. During the second week of asynchronous work, we will invite the participants to engage with a repository of resources (e.g., TBD readings from both academic and non-academic sources, videos, documentaries, podcasts, etc.) and socially annotate (e.g., through the Hypothes.is tool; Kalir & Garcia, 2019) the same for further collective discussion. On the day of the workshop, we will host a 3-hour synchronous session where we will facilitate group discussions around the generated shared artifacts. This session will consist of four parts: (a) introductions building off of the first week's asynchronous activity (~30 mins); (b) discussion of the socially annotated resources to identify themes and questions that connect SFF with LS frameworks and theories (~40 mins), and (c) finally work in smaller groups of 2-3 people to co-create a short story, illustration, or animation discussing a theme of their choice. The generated artifacts and resources will sustain workshop participation beyond the synchronous time and make room for further collaborative undertakings in the form of a possible anthology of stories and essays.

Organizer's backgrounds and intended audience

The two organizers are Suraj Uttamchandani and Deborah Dutta. Suraj is an Assistant Professor of Learning Sciences at Adelphi University and an enormous SFF nerd. His scholarship has centered on the political and ethical dimensions of learning activities, including for LGBTQ+ youth and with and without technology. He writes fiction often and uses speculative texts in his teaching around STEAM education concepts and digital media literacies. Deborah is a Senior Research Fellow at the Institute of Rural Management Anand (IRMA) and an environmental educator. Her work has centered around the intersection between learning sciences, community-based practices, and socio-technical systems, especially in the domain of food and agrarian practices in India. With a keen interest in different forms of creative expressions, she has illustrated a number of comics, children's texts, and short essays. They are both passionate about the role of science fiction and fantasy as entertainment,



art, and investigation, and seek to build out new projects that animate SFF for the learning sciences. Knowing the multitude of possibilities, they call this workshop together to think together with like-minded scholars about the existing work and paths forward in this area. Suraj and Deborah have co-facilitated an ISLS workshop before (with Gayithri Jayathirtha and Vishesh Kumar) at ISLS 2021: “Towards a Transnational, Decolonial, and Non-WEIRD Learning Sciences: Implications of perspectives from beyond ‘the west.’”

Our intended audience is educational researchers and practitioners, especially learning scientists, who are interested in genre fiction and its potential in designing creative learning environments and questions. We anticipate that some scholars will be consumers of SFF in their personal life but not in their scholarship, whereas others have engaged some of the relevant scholarly research previously in their work. Participants will not be expected to have considered the pedagogical connections between SFF and the learning sciences, but we hope they will be passionate consumers of genre fiction, whether in text form or in other media.

References

Bell, D. (1992). The space traders. In *Faces at the bottom of the well: the permanence of racism*. Basic Books.

Benoit, L., Thomas, I., & Martin, A. (2022). Ecological awareness, anxiety, and actions among youth and their parents—a qualitative study of newspaper narratives. *Child and Adolescent Mental Health*, 27(1), 47-58.

Crandon, T. J., Scott, J. G., Charlson, F. J., & Thomas, H. J. (2022). A social–ecological perspective on climate anxiety in children and adolescents. *Nature Climate Change*, 12(2), 123-131.

de Freitas, E., & Truman, S. E. (2020). Science fiction and science dis/trust: Thinking with Bruno Latour's Gaia and Liu Cixin's The Three-body Problem. *Rhizomes: Cultural studies in emerging knowledge*, (36).

Doctorow, C. (2018). I've Created a Monster! (And So Can You). *Frankenbook*. Retrieved from <https://www.frankenbook.org/pub/ive-create-a-monster>

Eschrich, J., & Miller, C. A. (2021). *Cities of light: A collection of solar futures*. Arizona State University's Center for Science and the Imagination.

Finn, E., & Wylie, R. (2021). Collaborative imagination: A methodological approach. *Futures*, 132, 102788.

Garcia, A., & Mirra, N. (2023). Other suns: Designing for racial equity through speculative education. *Journal of the Learning Sciences*, 32(1), 1-20.

Hicks, D. (2004). Teaching for tomorrow: how can futures studies contribute to peace education?. *Journal of Peace Education*, 1(2), 165-178.

Jenkins, H. (2006). *Convergence culture: Where old and new media collide*. New York University Press.

Kalir, J. H., & Garcia, A. (2019). Civic writing on digital walls. *Journal of Literacy Research*, 51(4), 420-443.

Liu, M., Williams, D., & Pedersen, S. (2002). Alien Rescue: A problem-based hypermedia learning environment for middle school science. *Journal of educational technology systems*, 30(3), 255-270.

Masamune, S. (2019). *Ghost in the Shell*. Kodansha America LLC.

Mawasi, A., Nagy, P., & Wylie, R. (2020). Systematic Literature Review on Narrative-Based Learning in Educational Technology Learning Environments (2007-2017). In Gresalfi, M. and Horn, I. S. (Eds.), *The Interdisciplinarity of the Learning Sciences*, 14th International Conference of the Learning Sciences (ICLS) 2020, Volume 3 (pp. 1213-1220). Nashville, Tennessee: *International Society of the Learning Sciences*.

Milkoreit, M. (2016). The promise of climate fiction: imagination, storytelling, and the politics of the future. In *Reimagining climate change* (pp. 171-191). Routledge.

Onoguwe, H. (2023). Death is Not an Ornament. In *Climate Action Almanac*. Center for Science and the Imagination, Arizona State University. <https://www.climatealmanac.org/pub/4tyf9901>

Oziewicz, M. (2017). Speculative fiction. In *Oxford Research Encyclopedia of Literature*.

Pelaprat, E., & Cole, M. (2011). “Minding the gap”: Imagination, creativity and human cognition. *Integrative Psychological and Behavioral Science*, 45, 397-418.

Salesse, M. (2021). *Craft in the real world: Rethinking fiction writing and workshopping*. Catapult.

Scalzi, J. (2005). What is Science Fiction Anyway? <https://whatever.scalzi.com/2005/10/20/what-is-science-fiction-anyway/>

Seligman, M. E., Railton, P., Baumeister, R. F., & Sripada, C. (2016). *Homo prospectus*. Oxford University Press.

Thomas, E. E. (2019). The dark fantastic. In *The Dark Fantastic*. New York University Press.

Walton, J. (2010). SF Reading Protocols. <https://reactormag.com/sf-reading-protocols/>

Wang, T., Uttamchandani, S., Zou, X., Hmelo-Silver, C. E., Rowe, J., & Lester, J. C. (2023). Learning With Stories: Characteristics and Learning Outcomes in Narrative-Centered Science Learning Environments. In *Proceedings of the 17th International Conference of the Learning Sciences-ICLS 2023*, pp. 1202-1205. International Society of the Learning Sciences.



Maximizing the ISLS 2024 Annual Experience: A Community-Based Workshop for Polishing Presentation and Conferencing Skills

Sarah Bichler, Katharina M. Bach
sarah.bichler@psy.lmu.de, k.bach@psy.lmu.de
Ludwig-Maximilians-Universität München

Abstract: This interactive and practical community-based workshop intentionally spans the before, during, and after the conference. Over multiple sessions: Kick-off & Presentation Skills, Practice & Conferencing Skills, and Reflections & Pursuing Opportunities we have three goals. 1) foster exchange between (new) members while they prepare for the annual meeting and create a network to fall back on during and following the annual meeting, 2) guidance for designing research talks and working out strategies to experience the annual meeting such that it meets personal expectations, and 3) joint reflection on the annual meeting experience and implementation intentions for pursuing opportunities. The workshop works towards making interactions around the presented research highly valuable for all ISLS attendees, offers professional development opportunities for all members and especially those who do not routinely get such support in their local contexts, and sustains the Learning Sciences society through building community and motivating continued engagement.

Description of the event

Aligning with the 2024 annual meeting theme of learning as a cornerstone of healing, resilience, and community, we want to support community building and productive exchange. Our goals are to 1) foster exchange between (new) members while they prepare for the annual meeting and create a network to fall back on during and following the annual meeting, 2) support members preparing their conference participation, including a) guidance for designing research posters/presentations, and b) working out strategies for members to experience the annual meeting such that it meets their expectations, and 3) joint reflection on the annual meeting experience and implementation intentions for pursuing opportunities. To achieve these goals, this is a long-tail workshop spanning the before, during and after the 2024 annual meeting.

Session 1: Kick-off & Presentation Skills: beginning of / mid-May 2024, 120 min, online

Session 2: Practice & Conferencing Skills: half-day 6 h June 8th or 9th, in person (hybrid/online optional)

Session 3: Reflections & Pursuing Opportunities: first week of July 2024, 60 min, online

Participation

Anyone who thinks this workshop benefits their ISLS 2024 annual meeting experience. However, our workshops might be most beneficial for first-time attendees, such as undergraduate and graduate students and participants new to conferencing or the ISLS. The workshop will be offered for a minimum of 6 and up to 20 participants. Requirements for participation are: applied before the deadline, commitment to iterate on presentation/poster design and talk, and active participation (sharing and giving feedback). Participants must attend ISLS 2024 (in person or remotely) and ideally have an accepted paper/poster.

Theoretical background, relevance and expected outcomes

A conference such as the ISLS annual meeting represents an opportunity to get to know other researchers in the field and learn about their research during presentations and informal exchanges. By sharing with others and listening, a conference can provide important new insights, skills, and inspiration essential to one's own work (Becerra et al., 2020). At the same time, conference attendance allows one to present one's own research and receive valuable feedback from others (McCarthy et al., 2004).

To have such an enriching experience and not be overwhelmed, a certain understanding of how to navigate or participate in a conference effectively would be beneficial. This is, however, not always given, especially for early career researchers (Becerra et al., 2020). Newcomer researchers benefit more from a conference when they get guidance and strategies for navigating it. Additionally, they have an advantage if arriving well-prepared for their paper or poster presentation to communicate their work understandably and convincingly (Sousa & Clark, 2017). Even though academic presentation and communication skills are fundamental for a successful academic career (Ohnishi & Ford, 2015), researchers may have little opportunity to prepare and practice for conference presentations in the everyday university setting. While research papers and



articles are available that give tips on how to work towards an academic career or navigate conferences (e.g., Chatzea et al., 2022), it is not routine practice to consult these resources before attending a conference.

Therefore, we propose a community approach to preparing the ISLS annual meeting, providing collaborative activities, hands-on work on participants' own contributions, and practice with peer and facilitator feedback and guidance.

The proposed interactive and practical community-based workshop is relevant to the field and annual meeting on several dimensions: First, it supports participants in delivering high-quality presentations, talks, and focused conversations around their research, ultimately making interactions around the presented research more valuable for all ISLS attendees. Second, it is a resource and offers a toolbox, especially for those researchers who do get little or no guidance in their local contexts. Third, it sustains the Learning Sciences community through onboarding members, preparing them for a meaningful experience, inviting participation and motivating continued engagement with the community. Our workshop design intentionally spans the before, during, and after the conference to build community beyond supporting presentation and conferencing skills. In this workshop, we learn together how we most effectively engage in the scientific discourse, but we also bring people together to sustain the environment in which this discourse happens. Further, this workshop elicits the various expectations and goals different people have for the conference experience, fostering respect, uptake, and integration of various ways of scientificness within the community.

Outline of workshop activities

Session 1: Kick-off and presentation skills

- *Aim:* Laying the groundwork for trustful interactions during the conference & presentation skills intro
- *Activity 1:* Icebreaker and getting to know each other (20 min)
Name, pronouns, conference experience, research topic (whole group or breakout rooms, depending on N); Ice-Breaker game (e.g., find similarities with your group in break-out rooms)
- *Resources:* Presentation skills & rhetoric (60 min)
Share knowledge, tips, and practical advice on “preparing meaningful conversations about your research”. How do we “make it stick”? Strategies for ensuring the audience hears and remembers the gist of your story
- *Activity 2:* Your research story (30 min)
Participants apply strategies to their own research talks at the conference (brainstorm, formulate, reflect: your research story communicated effectively in 10 or 3 minutes)
- *Summary and goodbye* (10 min)
Takeaways + preview half-day session. Optional: individual coaching sessions before session 2.

Session 2: Conferencing skills & research talk simulation

- *Aim:* Professionalizing research talks & preparing conference interactions
Participants bring their (final) posters, slides, and revised drafts of talks to the 6 h in-person session.
- *Activity 1:* Icebreaker and getting to know each other in person (25 min)
Ice-breaker game (e.g., Bingo) to create a comfortable atmosphere and community among the participants, setting individual and community goals for the workshop
- *Activity 2:* Expectations for the annual meeting (25 min)
Individual work + whole group sharing: what do you want to accomplish during the annual meeting?
- *Activity 3 & Resources 1:* How to get the most out of the annual meeting (40 min)
Using digital facilitation tools, we work out plans for achieving the goals participants have set for the annual meeting. We address challenges and fears and propose strategies. Participants make implementation intentions by listing three goals they want to achieve and how/when. Collaborative viewing of the conference program and creating personal schedules.
- *Q & A* (10 min)
Room for questions and sharing.
- *Break* (15 min)
- *Activity 4 & Resources 2:* Body language and rhetoric (75 min)
Participants give their talk in a small group. We observe and give feedback. We learn about gestures, facial expressions, posture, and linguistic aspects (e.g., choice of words, stylistic devices) that we use unintentionally and can use intentionally to make our research talks more precise and enjoyable. Lead



by peers and facilitators. Individuals set goals for improving their research talks. Second round of practice talks with feedback on the specific aspects each person focused on.

- *Break* (30 min)
- *Activity 5: Simulation* (120 min)
We simulate the presentation at the conference. Each participant gives a full presentation for the whole group. Participants and facilitators give feedback for final improvements. Optional: record the presentation (using participants' own phones) for their own use or short coaching with facilitators. We might split into two larger groups, depending on the number of participants.
- *Summary and goodbye* (20 min)
- *Feedback from participants, questions.*

Session 3: Reflections and pursuing opportunities

- *Aim:* Reflect on the annual meeting experience and takeaways + implementation intentions for follow-ups.
- *Activity 1: Presentation and conferencing skill reflections* (30 min)
Using guiding questions, we reflect on the annual meeting (Padlet or else for anonymous sharing). This reflection will be on two levels: conference experience and participants' presentation/poster talk. Highlight accomplishments, identify the "room to grow"
- *Activity 2: Pursuing opportunities* (20 min)
Individually, participants reflect on their personal experiences and opportunities that came up during the conference (e.g., a conversation with a fellow researcher, a presentation that sparked interest, etc.). They share with the group. Participants discuss what follow-up action they can take to pursue these opportunities. Participants make implementation intentions to pursue 1-3 opportunities (what, when, and how).
- *Summary and goodbye* (10 min)
- *Feedback regarding workshop format and the content. Goodbye.*

Call for participation

We will solicit participation via the ISLS 2024 annual meeting webpage, on the ISLS homepage, through ISLS mailing lists, the Education Committee, on social media (X, Facebook, etc.), and through mailing lists at local institutions accessible to the facilitators and their personal networks. We will use our personal and professional networks, for example, of the Munich Center of the Learning Sciences, to inform potentially interested people about the opportunity to participate in the workshop.

While there are definite benefits for undergraduate or graduate students, first-time conference attendees, or new ISLS members, we invite all members who want to professionalize their presentation and conferencing skills and to build community within the ISLS to participate in this workshop. We aim for all workshop members to deliver high-quality presentations of ISLS research, design personally meaningful and rewarding conference experiences, and connect with the ISLS community. For these goals to be achieved, participants should commit to active contributions, respectful and kind feedback practices, and openness to iteratively refine their work.

Workshop facilitators

Sarah Bichler received her PhD in Psychology and Learning Sciences from the LMU Munich in 2019, worked as a postdoctoral scholar at the University of California, Berkeley, and is continuing her postdoctoral research at LMU München. As a member of ISLS for more than five years, she actively contributes to the Education Committee and NAPLeS. Sarah has taught academic skills courses and workshops for undergrad and graduate students, organized peer feedback and collaborative conference preparation, a student conference at the Munich Center of the Learning Sciences, and has extensive experience in teaching, advising, and mentoring.

Katharina Bach started her doctoral research on learning and instruction at the LMU Munich in 2022. Prior, she graduated from the Master's program in Psychology and Learning Sciences at the LMU and conducted research at several universities (e.g., University of California, Berkeley, and UCLA) and institutes (e.g., German Youth Institute). Katharina teaches several classes on academic skills and educational content. Moreover, she is a trainer for effective communication and rhetoric and is mentoring several students in her free time.

References



Becerra, L. A., Sellers, T. P., & Contreras, B. P. (2020). Maximizing the conference experience: Tips to effectively navigate academic conferences early in professional careers. *Behavior Analysis in Practice*, 13(2), 479–491. <https://doi.org/10.1007/s40617-019-00406-w>

Chatzea, V.-E., Mechili, E. A., Melidoniotis, E., Petrougaki, E., Nikiforidis, G., Argyriadis, A., & Sifaki-Pistolla, D. (2022). Recommendations for young researchers on how to better advance their scientific career: A systematic review. *Population Medicine*, 4(September), 1–17. <https://doi.org/10.18332/popmed/152571>

McCarthy, J. F., McDonald, D. W., Soroczak, S., Nguyen, D. H., & Rashid, A. M. (2004). Augmenting the social space of an academic conference. *Proceedings of the 2004 ACM conference on Computer supported cooperative work*, 39–48. <https://doi.org/10.1145/1031607.1031615>

Ohnishi, S., & Ford, J. H. (2015). Student seminar program for improving academic presentation skills for PhD students in science: The effect of language background on outcome. *International Journal for Researcher Development*, 6(1), 57–76. <https://doi.org/10.1108/IJRD-09-2014-0027>

Sousa, B. J., & Clark, A. M. (2017). Getting the most out of academic conference attendance: Five key strategies. *International Journal of Qualitative Methods*, 16(1), 1609406917740441. <https://doi.org/10.1177/1609406917740441>



Towards a Transformative Action Research Network

Sameer Honwad , University at Buffalo (SUNY) sameerho@buffalo.edu

Preeti Raman, Toronto Metropolitan University ipraman@torontomu.ca

Jim Slotta, University of Toronto, jim.slotta@utoronto.ca

Paulo Blikstein, Columbia University, paulob@tc.columbia.edu

Akshay Kedari, Jnana Prabhodini, akshaykedari18@gmail.com

Christopher Hoadley, University at Buffalo (SUNY) tophe@buffalo.edu

Yeshi Paljor, University at Buffalo (SUNY), yeshipal@buffalo.edu

Shakuntala Devi Gopal, University, University of Arizona, sgopal91@gmail.com

Devayani Tirthali, independent researcher, devayani.tirthali@gmail.com

Abhijit Kapre, University of Toronto, abhijit.kapre@gmail.com,

Renato Carvalho, University of Toronto, renato.carvalho@utoronto.ca

Abstract: This workshop will bring together transformative action projects from around the world to share insights, challenges and varying epistemologies of practice. We will share our progress and reflections to collectively build-on the different approaches to critical pedagogy that lead to transformative action in unique cultural contexts across low and middle-income countries around the world. The goal of this workshop is to form a knowledge network of researchers, practitioners and community members that are engaged in transformative action.

Introduction

In his 2017 Presidential address, Bill Sandoval raised an important goal of fostering awareness of, and attention to teaching and learning in the global south. He called for more studies that examined contexts other than that of North America, Europe and Asia. In alignment with this priority, there has been some growth of a community of scholars who have matured in our understanding of what learning sciences research can look like in the global south, particularly in the form of “transformative action” projects where the research is deeply participatory in nature, and connected with some form of empowerment and transformation within participating communities. This workshop is being convened by a group of scholars who presented a symposium at last year’s ISLS annual meeting titled, “Moving Towards Critical Pedagogy for Transformative Action: Learnings From Research Partnerships” (Honwad et al., 2023). This session included five projects, presenting our studies of (1) how critical action approaches were facilitated by teachers in Bengaluru, India; (2) how educators at a tinkering lab in rural India connected materials and learning experiences in the tinkering lab to community problems; (3) how science teachers in Guyana brought their socio-political identities to their classroom settings; (4) how podcasting was used by youth in the Coeur D Alene nation to understand community based environmental problem solving; (5) how education approaches in Brazil create a culturally relevant learning experience for learner. Our goal for the workshop is to engage these projects in a deeper dive into their respective methodologies, theoretical frameworks, and epistemic positions regarding transformative action. An important outcome will be to support our solidification of a scholarly network for transformative action research. We recognize the need for deepening our discourse around transformative action research. We seek to expand the context of this work, as well as to strengthen our own methodological approaches and theoretical perspectives. This workshop will offer opportunities for anyone engaged in such work, as well as for those who are interested in exploring this space.

This workshop will bring together the various projects from last year’s symposium, as well as several others who are interested in this broad area of work. Each participating project will explicate an area of challenge and need, and the first part of the workshop will focus on supporting every project with reflective discourse and work on these needs. In the second part of the workshop, we will explore ways of establishing and sustaining a network of transformative action research within the learning sciences. We will seek ways to connect projects during the calendar year – not just at the annual meeting. We will find ways to celebrate our project successes, connect projects with resources and consultations, and support the careers of our colleagues from the global south. This workshop will explore the various theoretical frameworks and methodologies employed in our work and try to establish an ongoing discourse around such work in the learning sciences.

Learning environments designed within the framework of transformative action challenge educators and students to critically think about issues such as: how can all voices and contributions in the learning environment be heard and honored; how can issues discussed in the learning environment center around social justice; how can knowledge generated in the learning environment be used by local communities so that the knowledge generation process has relevance to everyday life issues faced by the learners and their communities (Bangs &



Davis, 2015; Jemal & Bussey, 2018). This work also builds on Freire's (1970) assertion that the educational process must interweave theory, reflection, and action as a means to advance the broader society towards social change and justice. This approach to the design of learning environments is particularly relevant in a moment in which the world is experiencing a series of concurrent crises—environmental, geopolitical, civilizational, economic, health—each with direct and profound effect on students. The transformative action approach responds to research that suggests that emotional responses to situations perceived as oppressive and overpowering (e.g., systemic racism and other forms of discrimination, war, poverty, etc) might be alleviated by engaging students in some form of committed action (Charlés, 2010; Ridley et al., 2020).

While research in the field of learning sciences provides some guidance as to how to design learning environments for transformative action, most of this research is conducted in economically wealthy parts of the world (United States, Europe, Australia). There is a need and a responsibility for learning scientists to address learning in all of its forms and contexts, which can inform our deeper understanding of how learning occurs in diverse contexts and situations. These forms of engagement have proven to be a challenge even in high-income nations (Basu & Calabrese-Barton, 2010), with some hard-won advances made by educational researchers. Lower and middle-income settings introduce an additional set of challenges, varying greatly in terms of their educational systems, local cultures, languages, and the specific issues that may be oppressive to students and local communities. The learning sciences bring a wealth of understanding about how to engage such diversity and sustain deeply situated learning, and participating projects will provide examples of how their approaches were defined and facilitated in various parts of the globe and various contexts (formal, informal, K-12, adult, etc).

Structure of the session

This workshop will engage participants for a full day, providing opportunities for both synchronous hybrid participation in the morning, and continued asynchronous participation after the event. The workshop will begin with project presentations, totaling 90 minutes, presented to a broad audience of those attending face to face and in hybrid context. Each project will include information about the partnership, relevant research challenges, and directions and insights around transformative action. Each project will specify their methodological, intellectual, ethical and practical dilemmas and solicit ideas to catalyze their research and practice. We will maintain a community Knowledge Board, allowing participants to add their ideas and build connections during this initial session, and asynchronously beyond this time (and even after the event). We will video record these presentations and add them to the Knowledge Board, allowing for sustained documentation and asynchronous knowledge work. Next, we will organize a set of table-group discussions comprising two or three projects that represent particular issues or discussions within the area of transformative action research, including particular methodologies, cultural contexts or practices, or specific challenges. Workshop participants will join one of these discussions, and each table will document its progress over a 1-hour period. There will then be a 30-minute presentation session, followed by a discussion of cross-cutting ideas or issues. After lunch, we will focus on our future as a network of scholars and practitioners. We will employ a design-oriented methodology, beginning with brainstorms of objective elements from our work, followed by a definitional phase where we articulate specific needs and elements for the network. For example: *How can we best support our global participants including teachers or citizens engaged in our work? What are the challenges faced by scholars in the developing south, and how could this network support them, professionally? What aspects of our work should be promoted or celebrated in ways that may not be afforded by normal publication channels? What forms of resources can we curate, as a community? How can we leverage our collective strengths in terms of human, technological and knowledge resources?* We will establish a transformative action research network, culminating in an action plan and next steps for any who are interested.

Presenting projects

While we will have a call for participation to this workshop inviting all learning scientists and practitioners engaged in transformative action research, the following projects have confirmed participation.

1. Critical action learning exchange (CALE)

James Slotta, Renato Carvalho

CALE is an international professional learning community (PLC) for educators dedicated to designing, enacting and sharing critical action curriculum that empowers students in responding to pressing, complex socio-environmental issues such as climate change, social justice, pandemics, and more. CALE applies Critical Pedagogy within a modern context of empowering teachers to help students overcome the sense of powerlessness



regarding overwhelming socio-environmental issues, and feel empowered as agents capable of responding to those problems. Over the past three years, we have designed the CALE activities, resources, and technology environments to support our programs, tested our design ideas through cycles of implementation with teachers, and continuously improved our various frameworks and design guides to help CALE become a sustainable community of practitioners (, 2021).

2. Technology design and collaboration in rural western India.

Akshay Kedari, Devayani Tirthali

Rural students across the world find it challenging to develop interests and motivation in science and technology related topics (Harris & Hodges, 2018). In rural western India, school is often perceived as an agent that introduces the youth to outside knowledge that is very different from the existing culture and tradition in the region (Jackson, 2003; Shiva, 2000; Goonatilake, 2001). As Pande (2001, pp 48) points out, “In their haste to run away from the village, the young men and women do not seem to have the time to understand their own village and their own people, nor do they receive any orientation towards this in school.” Therefore, it is an important undertaking to design a curriculum that focuses on connecting school related work with community-based practices.

3. Science teacher identity and classroom discourse in Guyana

Shakuntala Devi Gopal

Science education has historically had a tendency to call itself apolitical or neutral and consequently been unwelcoming to conversations surrounding injustice (Bazzul and Tolbert, 2019). Our work examines the sociopolitical factors that shape science teacher identity and how that identity informs pedagogical practices and classroom decision-making. Research on science teacher identity has established how identity can influence science teaching practices and pedagogical commitments (e.g., Helms, 1998); however, the relationship between science teacher identity and the increasingly sociopolitical nature of science education remains under-examined (Kokka, 2018). Youth must not only learn to decipher scientific complexities, but also the social, economic, and political factors that influence decision-making. This research asks whether science teachers see themselves as responsible for developing youth “critical consciousness” (Freire, 1970) i.e., the ability to recognize social realities that perpetuate inequities (Jemal, 2017), and why not if not.

4. Voices to hear

Sameer Honwad

Voices to Hear (V2H), a design-based research project that utilized oral traditions of storytelling, engaged Native American youth ages 12-25 in learning about complex environmental challenges faced by the Coeur d'Alene (CDA) nation. By asking students to reflect on environmental decision-making processes in their communities they will advance the practice of merging two different knowledge systems (Eurocentric- mainstream/dominant science perspective, and Indigenous – traditional knowledge) to resolve environmental problems, and enable sustainable decisions in their everyday lives. Our work spotlights the historical atrocities that have led to several environmental, social, and political consequences, and also embolden students to consider the ways they can be activists and community leaders (Ginder & Kelly, 2013). Through the podcasting process, students learned about environmental issues through the lens of different knowledge systems (Indigenous and Eurocentric) by hearing stories told by CDA Elders, explanations provided by natural resource scientists, and observations made by other community members.

5. Making as empowerment and community-building in the Brazilian Amazon

Paulo Blikstein, Raquel Coelho, José Valente, Eliton Moura

We designed a project in Brazil to engage with multiple communities to research their making practices and the diverse perspectives that underlie them. The locations include two *quilombola* communities (formerly enslaved people): a community of Afro-Brazilian weavers, and a Samba school. In the first community (clay pot makers in the Northeastern Amazon), the production of clay objects was deeply intertwined with spirituality. The collection of clay could only be done once a year under strict religious rules dating decades back. In a second *quilombola* community, a few hours away, women made cosmetics from native seeds. We also found seamlessly-



integrated spiritual and empirical practices here with an additional and political component. The community leader reported that they had to organize and create an association to optimize production, which made them realize something entirely unrelated to cosmetics. Once they had an association, their voices coalesced into an amplified and powerful one.

References

Bangs, R., & Davis, L. E. (2015). America's racial realities. In R. Bangs & L. Davis (Eds.), *Race and social problems: Reconstructing inequality* (pp. 3-14). New York: Springer Science and Business Media.

Bar-Tal, D. & Harel, A. S. (2001). Teachers as agents of political influence in the Israeli schools. *Teaching and Teacher Education, 18*, 121-134.

Basu, S. J., & Barton, A. C. (2010). A researcher-student-teacher model for democratic science pedagogy: Connections to community, shared authority, and critical science agency. *Equity & Excellence in Education, 43*(1), 72-87.

Bazzul, J. & Tolbert, S. (2018). Love, politics and science education on a damaged planet. *Cultural Studies of Science Education, 14*, 303-308.

Braa, D., & Callero, P. (2006). Critical pedagogy and classroom praxis. *Teaching Sociology, 34*(4), 357-369.

Charles, S. T. (2010). Strength and vulnerability integration: a model of emotional well-being across adulthood. *Psychological bulletin, 136*(6), 1068.

Curnow, J., & Jurow, A. S. (2021). Learning in and for collective action. *Journal of the Learning Sciences, 30*(1), 14-26.

Davies, B. & Harré, R. (1990). Positioning: The Discursive Production of Selves. *Journal for the Theory of Social Behaviour, 20*(1), 43-63.

Deshpande, S. (2006). Exclusive Inequalities: Merit, Caste and Discrimination in Indian Higher Education Today. *Economic and Political Weekly, 41*(24), 2438-2444. JSTOR.

Engeström, Y. (2015). Learning by Expanding: An Activity-Theoretical Approach to Developmental Research (2nd ed.). Cambridge University Press.

Espinoza, O., & González, L. E. (2016). The student movement in Chile and the neo-liberal agenda in crisis. In *Understanding Southern social movements* (pp. 192-209). Routledge.

Freire, P. (1970). *Pedagogy of the oppressed*. New York: Continuum.

Goonatilake, S. (2001). Anthropologizing Sri Lanka. In *A Eurocentric Misadventure*. Indianapolis: Indiana University Press.

Gilbert, A., & Yerrick, R. (2001). Same school, separate worlds: A sociocultural study of identity, resistance, and negotiation in a rural, lower track science classroom. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 38*(5), 574-598.

Ginder, S. A., & Kelly-Reid, J. E. (2013). Postsecondary Institutions and Cost of Attendance in 2012-13; Degrees and Other Awards Conferred, 2011-12; and 12-Month Enrollment, 2011-12. First Look (Provisional Data). NCES 2013-289rev. *National Center for Education Statistics*.

Guha, R. (2017). India after Gandhi: The history of the world's largest democracy. Pan Macmillan.

Harris, R. S., & Hodges, C. B. (2018). STEM Education in Rural Schools: Implications of Untapped Potential. *National Youth-At-Risk Journal, 3*(1), 3-12.

Helms, J.V. (1998). Science--and Me: Subject Matter and Identity in Secondary School Science Teachers. *Journal of Research in Science Teaching, 35*(7), 811-834.

Honwad, S., Gengarely, L., Glenn, M., Froborg, E., Clyde, M., & Andreozzi, H. (2023). Schoolyard SITES: School-community Partnership to Learn about Teaching Locally-Relevant Citizen Science. In *Proceedings of the 17th International Conference of the Learning Sciences-ICLS 2023, pp. 1935-1936*. International Society of the Learning Sciences.

Jemal, A. (2017). Critical Consciousness: A Critique and Critical Analysis of the Literature. *Urban Rev, 49*(4), 602-626

Jemal, A., & Bussey, S. (2018). Transformative action: A theoretical framework for breaking new ground. *EJournal of Public Affairs, 7*(2), 37-65.

Pande, A. (2001). Environmental education in rural central Himalayan schools. *The Journal of Environment Education, 32*3, 47-53.

Ridley, M., Rao, G., Schilbach, F., & Patel, V. (2020). Poverty, depression, and anxiety: Causal evidence and mechanisms. *Science, 370*(6522).



Exploring the Content and Structure of a Framework for Learning Progressions for K-12 Data Science Education

Katherine M. Miller, Concord Consortium, kmiller@concord.org

Chad Dorsey, Concord Consortium, cdorsey@concord.org

Zarek Drozda, Data Science 4 Everyone, zarekd20@uchicago.edu

Abstract: There is no longer debate about whether data science education (DSE) has an important role to play in K-12 education. However, while DSE is growing quickly as a field within educational research, it is still nascent, especially in regard to K-12, which creates a troubling dichotomy with the quickly increasing uptake of DSE work among K-12 practitioners and developers. As such, there is a need for a framework for learning DSE at the K-12 level which could serve as a guide to practitioners and researchers alike. There is an ongoing attempt by leaders in the field to build such a framework through facilitation of a series of workshops across the field with the goal of building a consensus Framework for Learning Progressions for K-12 DSE. This ISLS Pre-conference Workshop would serve as an opportunity to bring the learning science field efficiently into that process.

Introduction

While data science education (DSE) is growing quickly as a field within educational research, it is still nascent, especially in regards to K-12 teaching and learning, which creates a troubling dichotomy with the quickly increasing uptake of data science education work among K-12 practitioners and developers (Drozda et al., 2022; National Academies of Sciences Engineering and Medicine [NASEM], 2023). As implementation by practitioners and others supporting the field accelerates, such implementation occurs with little guidance from research-based understanding about what learners need to know and be able to do with data and when within the course of their learning these aspects are appropriate (Gebre, 2022; Israel-Fishelson et al., 2023; NASEM, 2023). This lack of cohesion around the boundaries and foundation components of learning with and about data also stands as a barrier to growth of the field itself, as researchers begin to investigate important questions without the benefit of a clear unifying framework or consensus about the field's grand challenges and focal research areas (Gould et al., 2016; Miller & Yoon, 2023; NASEM, 2023). As such, there is a need for a framework for learning data science education at the K-12 level which could serve as a guide to practitioners and researchers alike. In an attempt to build such a framework, the Concord Consortium and Data Science 4 Everyone have joined together, with seed funding from NSF and the Valhalla Foundation to facilitate a series of workshops across the field with the goal of building a consensus Framework for Learning Progressions for K-12 DSE. This ISLS Pre-conference Workshop would serve as an opportunity to bring the learning science field efficiently and effectively into that process.

Background and relevance

There is no longer room for debate about whether data science education has an important role to play in K-12 education. A stable of research studies, software tools, and curriculum materials has firmly established the topic's relevance (e.g., Drozda et al., 2022; Frischmeier et al., 2021; Israel-Fishelson et al., 2023; Jiang et al., 2022). National networks and coalitions have raised awareness across multiple groups of interest including a recent National Academies workshop *Foundations of Data Science for Students in Grades K-12* which established K-12 DSE as a crucial and growing education research field (NASEM, 2023). The end result of this movement has been a rising swell of interest and momentum across multiple groups of interest including researchers from many fields within education and a growing awareness and legitimization of the topic among K-12 educators and administrators.

While calls for K-12 data science education research draw from a rich history of statistics education research including learning trajectory development particular to that field (e.g., Franklin & Bargagliotti, 2020), the National Academies workshop highlighted the need for bringing somewhat siloed fields of research together to build a more comprehensive, consensus understanding of the scope of data science education. The workshop framed the importance of research in areas as far-ranging as identifying the role for tools and technologies in data science education, understanding the needs for teacher preparation for data science education, answering questions about what data science education looks like in different educational settings, and identifying and encouraging just and ethical approaches to data science education (NASEM, 2022).



Whether identifying the general need for better understanding student learning or calling out specific needs for broadened participation, descriptions of need related to research share a common thread. In all cases, participants, panelists, and co-chairs point to the need for better understanding of research-based learning progressions, identifying the importance of overall coordination and clarity across data science education research (Miller & Yoon, 2022; NASEM, 2022; Rosenberg & Jones, 2022). Any initiative aimed at developing learning progressions or related frameworks must consider both the history of the concept's development and the overall positioning of its work within that history. As practitioners and providers tackle the challenge of creating materials and preparing students for the skills and understandings necessary for data fluency, the existence of research to guide their work is essential. Learning progressions have sway across multiple contexts including, but not limited to, state and national standards, large-scale assessments, and classroom practice (NSF, 2011). While actively identifying the breadth of literature and practice around learning progressions as key inputs to our development process, the work of this framework building will take audience into consideration as an equally important input. Given the nascent state of the field of data science education, many different groups stand to benefit from the resulting framework. The important audiences for this work are multiple, broad, and varying, and the potential applications to which it may apply comprise an equally broad set.

The effort to design a consensus framework for learning progression for K-12 DSE began with an NSF funded workshop in October 2023, *A Framework for Learning Progressions for DSE*. This workshop brought together educational researchers, professional learning coaches, and practitioners for a series of brainstorming sessions which explored possibilities for the structure and functionality of learning progressions for DSE as well as an initial attempt to map the content of those progressions. It resulted in an initial high-level outline of strands of learning for DSE. Building on that work, over the next several months, a series of design focus groups will be held which will gather expert input from a breadth of backgrounds, experiences, and perspectives that represent the full spectrum of data theory and practice, spanning higher-education, industry, K-12 practitioners, and students directly. The goal of these focus groups will be to solicit knowledge and expertise on the knowledge, skills, dispositions, and critical thinking tools students should gain by the time they graduate as relates to data literacy, data analysis techniques, and other data-related technology. The work is deliberately focused toward generating an ongoing line of work intended to engage interest groups going forward. In that vein, the proposed activities will generate a framework solid enough to inform work across both research and development, yet flexible enough to evolve and incorporate the many new findings certain to arise from each.

Organizers' background information

The effort to develop a consensus framework for learning progressions for K-12 data science education is being led by Data Science 4 Everyone (DS4E) and the Concord Consortium, two non-profit organizations dedicated to supporting the teaching and learning of data literacy. As such, the organizers of this proposed workshop are representatives from both organizations.

Katherine Miller, a Research Associate for Data Science Education at the Concord Consortium received a doctorate in the learning sciences from the University of Pennsylvania, where her dissertation work focused on designing and implementing a workshop for in-service teachers on teaching data literacy in their high school science classrooms. Dr. Miller has spent the last few years enmeshed in the emerging data science education research community, leading meet ups at education research conferences across the field. She has designed and facilitated multiple workshops for educational researchers, including the NSF funded workshop on *A Framework for Learning Progressions for DSE* which launched this venture and on which she was a Co-PI.

Chad Dorsey is the president and CEO of the Concord Consortium and has been working in the data science education space since before it was a coherent field or community. He has extensive experience presenting and leading workshops at conferences across disciplines and fields. Through his work at the Concord Consortium, Chad has become a leading voice in the Data Science Education community. He is PI or Co-PI on over a dozen projects seeking to advance data and digital literacy, including the NSF funded workshop on *A Framework for Learning Progressions for DSE*.

Zarek Drozda is the director of DS4E, a national initiative and coalition based at the University of Chicago. He was foundational to the launch of DS4E and has worked over the last four years to organize and develop a coalition of now 1000+ education leaders seeking to advance data science and data literacy education in K-12 schools. Zarek has designed, organized, and implemented dozens of workshops, professional learning opportunities, networking events, and other opportunities for cross-field pollination, including both the National Academies Workshop and the NSF workshop. This proposed workshop builds directly on those two workshops.

Workshop agenda



The intended audience for this workshop is anyone interested in the field of data science education even if they are not currently conducting research in the field. All will be welcome, and though we expect 15-30 participants, we will gladly take up to 40 participants on a first come first serve basis by registration for the event. The workshop is envisioned to be a half-day (4 hour) interactive session in which participants engage with the results of the NSF workshop from last fall as well as the focus group sessions which will be held over the course of the next five months, provide feedback, and envision next steps for the project.

Themes and goals

The theme of this workshop is a focus on consensus building around what students should know and learn about working with data. This is a salient topic for many learning scientists and invokes themes on ethics, accessibility, and social justice (e.g., Louie, 2022). While the goal of the workshop is to develop a list of outcomes for student learning with and about data by the end of high school, compare that list of outcomes to those created by other groups of interest, and then brainstorm how the learning science community can focus their research to areas that are less well developed, the diversity of the experience and input from the group of participants will likely surface themes held within the lens of criticality such as bias, ethics, and the sociopolitical implications of an increasingly rich world (Louie, 2022; Woods et al., 2024).

Outline of agenda for workshop

The workshop will begin with participants in small groups discussing the question, *“If there were an imaginary high school exit exam about data in 2030, what should be covered?”* This discussion will then be guided into a more focused development of specific outcomes which are concise and in language accessible to the general public. Once each group has developed their list, the lists from each group will be combined, and a full group discussion will allow for outcomes to be combined, reworded, and then ranked for importance. The ranking will use a system where each participant is provided ten “votes” and can distribute those votes wherever they want among the list of outcomes, assigning one to each of ten different outcomes, or all 10 to the one they think is most important, or anywhere in between. This is the same process that will be used in the focus groups held throughout the first half of 2024. This process will take the first half of the workshop session and will result in a simple priority ranked list of data-related learning outcomes for all students to gain by high school graduation.

In the second portion of the workshop, participants will review the ranked lists from the focus groups held earlier in the year and again in small groups, discuss themes, surprises, and any conflicts they see. They will then be allowed to add any additional outcomes and change their votes if they wish. In the last hour of the workshop, participants will begin to organize the outcomes into strands of learning using the high-level framework developed during the NSF workshop last fall and discuss where there might be gaps in research for particular outcomes or at particular levels of learning. The resulting ranked list of outcomes and initial framework mapping will be digitized and made available to all participants as well as the larger community of focus group participants working to build consensus around the framework.

As most work will be conducted in small breakout groups, the workshop could be conducted with hybrid participation provided stable internet connections on both ends. A normal projector and screen are the only equipment needed for this workshop.

Expected outcomes

The expected outcomes of this workshop are a) a priority ranked list of data-related learning outcomes for all students to gain by high school graduation; b) a map of those outcomes sorted into strands of learning; and c) a list of potential areas for future research that would support the further development of the framework for learning progressions for DSE. All three of these outcomes will be made available to attendees as well as shared more widely within Concord Consortium and DS4E networks. Additionally, it is expected that significant networking and community building will occur during the workshop as participants will have multiple opportunities to work in small groups to share ideas and expertise and develop or strengthen connections with other researchers interested in data science education.

Draft call for participation

Both the Concord Consortium and DS4E have large, wide-ranging, existing networks of researchers interested in data science education. The call for participation in this workshop will be shared through both networks, including in newsletters and social media channels. The below text will be included in those solicitations.

Are you interested in Data Science Education (DSE)? Do you wish there was a framework to guide teaching and learning with and about data within K-12 education? The explosion of computing, “big data,” and



now artificial intelligence is quickly changing both daily life and many career paths, implying significant changes for what our education system needs to be teaching students. However, while data science education is growing quickly as a field within educational research, it is still nascent, especially in regard to K-12, which creates a troubling dichotomy with the quickly increasing uptake of data science education work among K-12 practitioners and developers. As such, there is a need for a framework for learning DSE at the K-12 level which could serve as a guide to practitioners and researchers alike.

The Concord Consortium and Data Science 4 Everyone are collaboratively spearheading an effort to design a consensus framework for learning progression for DSE K-12. This began with an NSF funded workshop in October 2023, which brought together experts from across the field for a series of brainstorming sessions which resulted in an initial high-level outline of strands of learning for DSE. Building on that work, a series of focus groups solicited knowledge and expertise on the knowledge, skills, dispositions, and critical thinking tools students should gain by the time they graduate as relates to data literacy. We want you to be a part of the process to design a consensus framework for learning progressions for K-12 DSE. This workshop will center around discussions of the question, *“If there were an imaginary high school exit exam about data in 2030, what should be covered?”* including small and large group knowledge sharing as well as comparisons of responses to this question from other sectors including teachers, students, and industry.

References

Drozda, Z., Johnstone, D., & Van Horne, B. (2022). Previewing the national landscape of K-12 data science implementation. In *Workshop on Foundations of Data Science for Students in Grades K-12*.

Franklin, C., & Bargagliotti, A. (2020). Introducing GAISE II: A guideline for precollege statistics and data science education. *Harvard Data Science Review*, 2(4), 1-9.

Frischemeier, D., Biehler, R., Podworny, S., & Budde, L. (2021). A first introduction to data science education in secondary schools: Teaching and learning about data exploration with CODAP using survey data. *Teaching Statistics*, 43, S182-S189.

Gebre, E. (2022). Conceptions and perspectives of data literacy in secondary education. *British Journal of Educational Technology*, 53(5), 1080-1095.

Gould, R., Machado, S., Ong, C., Johnson, T., Molyneux, J., Nolen, S., Tangmunarunkit, H., Trusela, L. & Zanontian, L. (2016). *Teaching data science to secondary students: The mobilize introduction to data science curriculum*. IASE 2016 Roundtable Paper.

Israel-Fishelson, R., Moon, P. F., Tabak, R., & Weintrop, D. (2023). Preparing students to meet their data: an evaluation of K-12 data science tools. *Behaviour & Information Technology*, 1-20.

Jiang, S., Nocera, A., Tatar, C., Yoder, M. M., Chao, J., Wiedemann, K., ... & Rosé, C. P. (2022). An empirical analysis of high school students' practices of modelling with unstructured data. *British Journal of Educational Technology*, 53(5), 1114-1133.

Louie, J. (2022). Critical data literacy: Creating a more just world with data. In *Workshop on Foundations of Data Science for Students in Grades K-12*

Miller, K., Yoon, S. (June 2023). *Supporting High School Science Teachers in Developing Pedagogical Content Knowledge for Data Literacy*. Paper presented at The Annual Conference of the International Society of the Learning Sciences (ISLS), Montreal, QC.

National Academies of Sciences, Engineering, and Medicine. (2023). *Foundations of Data Science for Students in Grades K-12: Proceedings of a Workshop*. Washington D.C.: The National Academies Press.

National Science Foundation. (2011, July 26). Learning Progressions Footprint Conference. *Learning Progressions Footprint Conference Final Report*. Learning Progressions Footprint Conference, Washington, DC.

Rosenberg, J., & Jones, R. S. (2022). A secret agent? K-12 data science learning through the lens of agency. In *Workshop on Foundations of Data Science for Students in Grades K-12*.

Woods, P. J., Matuk, C., DesPortes, K., Vacca, R., Tes, M., Vasudevan, V., & Amato, A. (2024). Reclaiming the right to look: making the case for critical visual literacy and data science education. *Critical Studies in Education*, 1-19.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant #DRL-2325871 as well as by funding from the Valhalla Foundation.



Healing Justice in Youth Organizations and Schools: Research Methods and Ethical Provocations

Ben Kirshner, Beatriz Salazar, Lex Hunter

ben.kirshner@colorado.edu, beatriz.salazar@colorado.edu, alexis.hunter@colorado.edu

University of Colorado Boulder

Solicia Lopez, Denver Community Organizer, soliciaelopez@redsolconsulting.com,

Jesica Fernández, Santa Clara University, jsfernandez@scu.edu

Rashida Govan, The Aspen Institute, rashidagovan@gmail.com

Elizabeth Mendoza, University of Colorado Boulder, Elizabeth.M3ndoza@gmail.com

Abstract: Many social justice youth organizations and school programs prioritize healing as a design principle and learning outcome. *Healing justice* frameworks emphasize people's well-being and, simultaneously, the transformation of institutions that cause harm (Ginwright, 2015; Page & Woodland, 2023). This move shifts the gaze from isolated individuals who are responsible for their mental health to a collective and political analysis of well-being, one that centers intergenerational relationships, justice, culture, and ancestry. This focus on healing and well-being among educators, young people, and community organizers calls for learning scientists who can work in partnership to leverage the tools of design, research, and evaluation. But HOW, precisely, should researchers study "healing?" It is immensely personal. It invites conversations about harms. It raises ethical questions. This half-day in-person workshop offers a space for people attending the ISLS conference to build relationships, explore questions, and strengthen our work through exchange and dialogue.

Pre-conference workshop rationale and aims

Rationale

Youth programs that center racial equity are increasingly bringing healing practices and aims into their work (Eagle Shield et al., 2020; Ginwright, 2015; Valladares et al., 2021). This healing justice lens calls for a "both/and" emphasis on personal well-being and societal change. Organizers and educators in communities of color draw on cultural traditions, including Indigenous Knowledge Systems, Chicana feminisms, and the Black African diaspora, to invite young people to anchor their activism in a healing framework (Anzaldua, 1981; Eagle Shield et al., 2020; French et al., 2020; Greene et al., 2021; Mendoza, 2022).

Healing justice raises provocative questions for research and evaluation. For example, practitioners have reported tensions between the evaluation requirements of program funders and the personal, difficult-to-measure elements of healing and well-being. How can youth programs document and assess their impact for participants in ways that are true to personal experiences of healing and well-being? Moreover, given that radical healing includes spiritual elements, how do we study such practices in ways that are affirming, humanizing, and respectful of the sacred? This pre-conference will provide a critical, hopeful space to examine tensions and dilemmas in radical healing with youth and will open new directions for community-engaged scholarship about healing justice.

Themes and questions addressed at pre-conference

Theme #1: Prefigurative practices in healing justice research

Engaging in prefigurative practices means trying to embody and enact with each other—in the here and now—the world we are trying to create for the future and across broader scales (Breines, 1989; brown, 2017). How do research teams embody healing practices as they carry out research about healing? What work do researchers need to do to develop self-awareness about their own experiences of trauma, harm, healing, and resilience? How does the researcher's life experience influence their approach to studying this topic? How can researchers take care of themselves while engaging in this work?

Theme #2: Ethics of healing justice research

Healing justice raises ethical questions about who participates, how to discuss issues of harm and trauma, and how to honor spiritual aspects of healing. Questions include: What ethical practices should guide research about healing in youth programs? For example, how can researchers handle experiences of harm or trauma in young



people's experience? How might our research honor spirituality and ancestral practices? What roles can young people themselves play in studying or evaluating youth education spaces they are part of? How do we include youth in ways that are affirming and humanizing?

Theme 3: Designing practical evaluation resources with and for educators

This workshop does not just address questions of theory and ethics, but also the design of useful and feasible resources for programs trying to assess or evaluate their goals related to healing and social justice. Questions include: what practical resources could be developed with and for grassroots youth programs that are required by their funders to evaluate their work? How can learning scientists work in partnership with youth and education organizations to strengthen their capacity to evaluate--both for reporting outcomes to funders (summative evaluation) and gathering information to improve (formative evaluation?)

Design of workshop

Workshop agenda

This is a half-day workshop. The workshop agenda is summarized in Table 1.

Table 1
Summary of Activities

Timing	Activity
8:30 - 9:30	<i>Coffee and light breakfast provided (using funds from grant)</i> Introductions, networking, and community-building Intention setting Frame key questions for the workshop
9:45 - 11:00	Breakout groups to dive into key questions and document their discussion <i>Topics include:</i> 1) Participatory action research for studying healing justice with youth 2) Ethical priorities for healing justice research 3) Practical resources for evaluating healing justice in youth programs 4) Researcher self-awareness in their experiences of harm and healing Break
11 - 11:15	
11:15 - 11:45	Each group offers succinct, 2-minute summary and key questions from their discussion (template provided to ensure focused report-out)
11:45 - 12:30	Open discussion of ways to stay connected and share ideas; explore shared projects; open time for relationship-building
12:30 - 1:30	Optional group outing for lunch

Post-workshop

We will facilitate emergent opportunities for participants to strengthen research collaborations and mentoring. This includes sharing the contact list of participants to facilitate networking, organizing a proposal to continue this conversation at the American Educational Research Association, and hosting a zoom call in the fall of 2024 to create space for people to discuss projects they are working on.

Expected outcomes and contributions

We expect that people who participate will walk away with stronger connections to other participants and will want to stay connected to the network. We anticipate that early career and graduate student scholars will experience affirmation and support for pursuing this area of research. This workshop will set the stage for subsequent contributions to the study of healing justice in youth programs and education spaces. This field is growing in popularity with educators and funders, but we lack guidance on how to study healing as a process or



outcome. Without ethical guidance and resources informed by learning theory, we risk leaving funders to define the agenda in ways that overlooks or even harms the precious qualities of healing spaces.

References

Breines, W. (1989). *Community and organization in the New Left, 1962–1968: The great refusal*. Rutgers University Press.

Brown, a. m. (2017). *Emergent strategy: Shaping change, changing worlds*. AK Press.

Anzaldúa, G. 1999. *Borderlands/La Frontera: The new mestiza*. 2nd ed. San Francisco: Aunt Lute Books.

Eagle Shield, A.E., Paris D., Paris, R., San Pedro, T. (Eds.). (2020). *Education in movement spaces: Standing Rock to Chicago Freedom Square*. Routledge.

French, B. H., Lewis, J. A., Mosley, D. V., Adames, H. Y., Chavez-Dueñas, N. Y., Chen, G. A., & Neville, H. A. (2020). Toward a psychological framework of radical healing in communities of color. *The Counseling Psychologist*, 48(1), 14–46. <https://doi.org/10.1177/0011100019843506>

Ginwright, S. A. (2015). Radically healing Black lives: A love note to justice. *New Directions for Student Leadership*, 2015(148), 33–44. <https://doi.org/10.1002/yd.20151>

Greene, A. C., Ortega-Williams, A., Page, C., & Davis General, A. A. (2021). Sacred conversations: Sharing journeys of healing justice with the field of critical youth mental health. In J. N. Lester & M. O'Reilly (Eds.), *The Palgrave Encyclopedia of Critical Perspectives on Mental Health* (pp. 1–15). Springer International Publishing.

Page, C., & Woodland, E. (2023). *Healing justice lineages: Dreaming at the crossroads of liberation, collective care, and safety*. North Atlantic Books.



Designing for Learning and Healing in the Academy

Krista Cortes, University of Pennsylvania, cortesk@upenn.edu

A. Susan Jurow, University of Colorado Boulder, susan.jurow@colorado.edu

Elizabeth Mendoza, University of Colorado Boulder, elizabeth.m3ndoza@gmail.com

Abstract: Through this half day workshop, we will weave sociocultural theories of learning, design, and healing to deepen participant attunement to the interconnection between learning and healing. Drawing on literature grounded in mind/body/spirit connection, and healing oral traditions, specifically *Curanderismo*, a Mexican Indigenous healing art, we define healing as a journey back to our intuition and an interconnection to ourselves, each other, and mother earth. This process involves making and unmaking—and learning and unlearning—to walk intentionally in systems of education, and further, to create spaces that recognize the brilliance and light of students. The workshop will embrace practical and embodied forms of reflection to name everyday practices embedded in colonization. Through storytelling we will provide examples of lived experiences in designing spaces of healing and learning. We conclude with community conversations and an activity to invite the emerging understandings of healing and learning to travel with the participants.

Theme and goals

I was told to stop saying "I feel" and say "I think".

Don't let them see you cry, it will make you seem weak.

I contort myself until I become what they want me to be.

I learned to police myself.

I tended to my body only when it could no longer carry me, and my spirit—my intuition—my superpower, became a whisper.

*-Dominant narratives of academia
voiced by women of color*

An aim of this half day workshop is to open up conversations in the field of the Learning Sciences about how we can cultivate healing in educational spaces (e.g., in the academy, schools, and workplaces) so that we can recognize and nurture students' brilliance. As reflected in the above quotes from women of color in the academy, the educational system is both a product of, and a source for, colonization that inflicts soul wounds (Love, 2019) onto everyone who participates in it while also landing more heavily on marginalized bodies and identities. Creating humane and equitable spaces grounded in healing is imperative, not only for retention but to normalize an ethic of care (hooks, 2018) in academia.

In this workshop, we make explicit the intersection of healing and learning through reflection, storytelling, and theorizing the design of learning environments for healing and learning. Toward this aim, we embrace healing as the integration of mind/body/spirit (Facio & Lara, 2009) and the development of transformative agency as the intentional shift in practices including asserting oneself, making decisions, influencing circumstances, and acting toward meaningful ends in ways that honor intuition and holistic movement (Lipponen & Kumpulainen, 2011; Rajala, 2016). We will engage in embodied activities aimed to help us (1) uncover and remember our own strengths and wholeness; (2) unlearn practices that contribute to fracturing of self in relation to engaging in the academy and doing research; and, (3) learn new practices for designing spaces for others to be brilliant. This workshop is open to everyone who seeks a desire for wholeness in relation to working with others on issues of learning, design, and education.

Theoretical background and relevance

Effective practices of colonization include the perpetuation of false dichotomies (e.g., productive/not productive) (Shahjahan, 2014), individuality over the community (Cajete, 2016), and the artificial separation of mind, body, and spirit (Facio & Lara, 2009). As referenced in the opening quotes, this includes, for example, learning to privilege the mind over the body, moving away from intuition and contorting to dominant social norms and expectations. It also looks like the need to produce continually or participate in forms of competition that pervade academia – for resources, publications, and recognitions. These practices can undermine the possibility of collective brilliance. These are also learned practices that accumulate over time through moment-to-moment interactions (Jurow & Pierce 2011).



We conceptualize healing as a journey back to participants' own intuition, wisdom, and light, which involves the integration of mind, body, spirit. Anzaldúa (2015) writes about the trauma of fragmentation, and healing, as a process of making and unmaking. Framed differently, healing can be seen as a process of learning (making) and unlearning (unmaking) in the journey back to an integration of self and movement toward honoring intuition. The unmaking can include the further breaking apart of broken pieces of ourselves to understand how we have embodied forms of colonization. From here arises a need to negotiate with ourselves and be intentional about how we want to realign or misalign with institutional norms. Healing then, does not have a resolution, but instead "requires that we shift our perspective" (Anzaldúa, p. 29). In this framing, central to healing is a connection to oneself, each other, and understanding Mother Earth as a relation and teacher. These guiding elements of healing are found across multiple traditional healing practices (Linklater, 2014; Avila, 1999; Hlela, 2018).

A theory of learning that embraces and reflects the nonlinearity of healing grounds the design of our workshop. We conceptualize learning as a continuous process of changing participation over time that involves a "synchronous attunement with the relations that form the web of all of life" (Rosado-May et al., 2020). Learning entails changes in who we are or how we see ourselves within our dynamic communities. It is never finished, but is a process of becoming (Wenger, 1998). This perspective aligns with decolonial approaches to healing that incite transformation, attunement, and shifts in perspectives.

Outline of planned activities

We have designed a set of activities to support the goals of our session. Throughout the workshop, the facilitators will lead the group in embodied practices that can support grounding in one's body (e.g., breathwork and movement), connecting to one's intuition (e.g., guided meditation, poetry), and deepening our Human-Earth interrelations (e.g. centering analogies for learning from nature). Our aim is to provide guidance on how participants might use these practices as practical pedagogical tools to support healing and move beyond individualistic and isolating spaces that can emerge in the academy.

Conceptualizing healing and learning - Reflections in our making and unmaking

We will open the space with an embodied activity to bring attention to the wisdom of our bodies. We draw centrally on oral healing traditions, in particular *Curanderismo*—an Indigenous Mexican healing art—and academic texts that center the unification of mind, body, spirit. We will bring participants into awareness to self-talk to engage in 'unlearning' and re-imagining. Specifically, we will work through four aspects of a reflective journey (Mendoza, 2022).

- naming the ways forms of oppression and colonization have become embedded in participants everyday self-talk (e.g., I am not good enough);
- tuning into the somatic and felt experience of that self-talk in the body (e.g., my chest feels tight); as well as the somatic experience in the body when participants feel as their most whole self;
- increasing body awareness with attention of what lessons might be gained from the body's wisdom (e.g., my chest was tight because I was worried I would disappoint everyone); and,
- setting an intention on what practice the participants want to 'try on' as they move forward through the rest of the conference.

Storytelling: Narratives for designing spaces of learning and healing

With the embodied and experiential grounding in the previous activity, we will move into the storytelling of one example of designing for healing and learning. We intentionally orient ourselves to storytelling as we will draw from our experiences creating and implementing a program aimed at healing academic harm which we have called HEAL - Healing, Empowerment, and Love. We will discuss our journey of implementing this program; the rejections, tensions, moments of success, and curiosities that have guided our work. Additionally, we will share the ways we have integrated literature into our practice in and through body awareness. This includes for example, the theorization of intuition-led facilitation, identifying the intangibles in design (Cortes, 2020), care(full) design (Mendoza & Jurow, 2023) - which draws on theories of design to center and normalize care and healing, and the way this foundation has traveled into other areas of our work and lives. During this storytelling session, we will embed prompts and opportunities for discussion and continued embodied reflection.

Developing pathways for healing in the Learning Sciences

As part of our closing reflections, we will invite participants to engage with the conceptualizations, stories, and practices of healing that we have collectively developed in the workshop. To make personal sense of them, we



will organize small group table talks. Each table will have a prepared deck of cards (a HEAL deck) with questions moving from self - practice - feeling - unlearning / learning. As facilitators, we will explain how this arc of reflective questions is linked to the perspectives on healing that grounded the workshop. Small groups will talk with one another about their responses to the prompts. The facilitators will then facilitate a discussion with the group that makes explicit key aspects of healing and their connections to learning and unlearning. The HEAL deck will be shared with the participants electronically as a practical takeaway from the workshop. It will be designed so that participants can add their own prompts and practices to support one another's further exploration and learning.

Expected outcomes and contributions

We hope to contribute to dialogues and practices that will enrich how healing is linked to learning—conceptually, practically, and pedagogically. Conceptually, we will engage centrally with theories of learning with healing through both literature and oral healing traditions. We will bring this framing into practical applications including embodied practices, a set of reflective prompts, and recommendations for free and easily available resources for deepening participants' knowledge of the healing practices we shared in the session as well as their histories. Pedagogically, we will engage with tensions and practices that center and normalize healing in the design of learning environments, including embedded practices of attuning to the wisdom in our bodies and returning to our intuition in design and in everyday interactions.

References

Anzaldúa, G. (2015). *Light in the dark/Luz en lo oscuro: Rewriting identity, spirituality, reality*. Duke University Press.

Avila, E., & Parker, J. (1999). *Woman who glows in the dark: A curandera reveals traditional Aztec secrets of physical and spiritual health*. Penguin Putnam, Inc.

Bang, M., Marin, A., Medin, D., & Washinawatok, K. (2015). Learning by observing, pitching in, and being in relations in the natural world. In M. Correa-Chávez, R. Mejía-Arauz, B. Rogoff (Eds.), *Advances in child development and behavior* (Vol. 49, pp. 303-313). <https://doi.org/10.1016/bs.acdb.2015.10.004>

Cajete, G. A. (2016) Indigenous education and the development of Indigenous community leaders. *Leadership*. 12:3, 364-376, <https://doi.org/10.1177/1742715015610412>

Cortes, K. L. (2020). *Designing New Scripts: Exploring the Everyday Practices of Blackness Amongst AfroPuerto Rican Mothers in California*. [Unpublished doctoral dissertation]. University of California, Berkeley.

Facio, E. & Lara, I. (2009) *Fleshing the spirit: Spirituality and activism in Chicana, Latina, and Indigenous women's lives*. The University of Arizona Press.

Hlela, Z. (2018). Learning through the action of research: reflections on an Afrocentric research design. *Community Development Journal*, 53(2), 375-392.

hooks, b. (1994). *Teaching to transgress: Education as the practice of freedom*. Routledge.

Jurow, A.S., & Pierce, D. (2011). Exploring the relations between "soul" and "role": Learning from the Courage to Lead. *Mind, Culture, and Activity*, 18(1), 26-42

Linklater, R. (2014). *Decolonizing trauma work: Indigenous stories and strategies*. Fernwood Publishing.

Lipponen, L., & Kumpulainen, K. (2011). Acting as accountable authors: Creating interactional spaces for agency work in teacher education. *Teaching and Teacher Education*, 27(5), 812-819.

Love, B. L. (2019). *We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom*. Beacon press.

Mendoza, E. (2022, September 22). Healing for real: Embracing the journey [Keynote]. Teachers of Color and Allies (TOCA) conference, Boulder, CO.

Mendoza, E., & Jurow, A.S. (2023-June). *Care(full) Design*. Grant Proposal.

Rajala, A., (2016). Expanding the chronotopes of schooling for the promotion of students' agency. In O. Erstad & J. Sefton-Green (Eds.), *Identity, community, and learning lives in the digital age* (pp. 107-125). Cambridge: Cambridge University.

Rosado-May, F. J., Urrieta, L., Dayton, A., Rogoff, B. (2020). Innovation as a key feature of Indigenous ways of learning (pp. 79-96). In N.S. Nasir, C.D. Lee, R. Pea, & M. McKinney de Royston (Eds.), *Handbook of the Cultural Foundations of Learning*. NY: Routledge.

Shahjahan, R. A. (2014). Being "Lazy" and Slowing Down: Toward Decolonizing Time, Our Body, and Pedagogy. *Educational Philosophy and Theory*, 47(5): 488-501.



The Hidden Majority: Examining the Inaccessibility Crisis as a Barrier to Equitable Education

C. Naomie Williams, Carnegie Mellon University, naomiew@cmu.edu
Margaret Ellen Seehorn, Grinnell College, seehorne@grinnell.edu
Mia Ellis-Einhorn, Haverford College, melliseinh@haverford.edu
Haiyi Zhu Carnegie Mellon University, haiyiz@cmu.edu
Vincent Aleven, Carnegie Mellon University, aleven@cs.cmu.edu

Abstract: An estimated 240 million children have a disability worldwide. Despite this 240 million representing 10% of all children globally, accessibility remains under considered in the design, development, and evaluation of educational technology. Prior work has established technology accessibility and inclusive curriculum as separate islands. With the number of disabled people increasing due to the COVID-19 pandemic, these islands need to unite to support society's most vulnerable learners. This full day workshop brings together an interdisciplinary community of researchers across learning science, accessibility, special education, and educational technology to define an emerging field. We will critically reflect on design, research practices, and lab culture to improve equity in education for students with disabilities. Results from this workshop include: a compilation of accessible research practices, a post-workshop space to facilitate collaboration, and new directions for future study.

Workshop description

Theme and goals

With our world downtrodden by consecutive and co-occurring crises, humanity must adapt to support our most vulnerable. At ISLS, we can start by bridging pre-existing gaps within our schools and extend the care needed for accessible learning to ourselves. The overarching goal of this workshop is to build collective understanding of accessibility within educational technology and the learning science community. Our goals include:

1. Share experiences and challenges designing, deploying, and evaluating educational technology for students with disabilities (SWDs) and their teachers.
2. Encourage attendees to explore accessibility in their study designs, research practices, and lab culture.
3. Co-design a living manifesto for accessible educational technology and learning science research.

Theoretical background

Accessibility is the practice of providing people with and without disabilities access to the same content and functionality at the same time, and in the same place, with substantially equivalent ease of use (Shaheen & Lohnes Watulak, 2019; U.S. Department of Education & U.S. Department of Justice, 2010). Unequal access for people with disabilities is inaccessibility. Unaddressed inaccessibility is a global crisis hidden in plain sight. Despite the rise in socially conscious research, we've under-considered the largest minority group in the way we design and evaluate learning technology. The World Health Organization estimates 1.3 billion people, or 16% of the global population have a disability: making people with disabilities the largest minority worldwide (World Health Organization, 2023). Within this 16%, approximately 240 million are children (United Nations Children's Fund, 2021). In the United States, 15% of public-school students receive special education services (National Center for Education Statistics, 2023). These students experience a range of disabilities, with learning and developmental being the most frequent at 33% and 25% respectively (National Center for Education Statistics, 2023).

Special Education provides SWDs access to assistive technology, modified curriculum, and personalized instruction. These resources intend to dismantle barriers that prevent SWDs from receiving an equitable education. Likewise learning technology aspires to be a medium for improving access to education. However, to actualize this promise, the needs of SWDs and their teachers must be addressed. Acknowledging the gap within the field of learning technology is the first step. In a review of 47 studies examining mobile learning in K-12 classrooms, only 6 identified SWDs in their participants' demographics (Xie et al., 2017). This bias toward general education is not limited to mobile learning tools. Educational technology in general has neglected the needs of SWDs in its development and implementation (Jackson, 2003); resulting in decreased software usability, failure to address crucial learning needs, and increased teacher labor in special education classrooms (Fryia et al., 2009). Accessibility *within* learning technology is an underdeveloped body of work, where impact on SWDs is



underdiscussed. Although accessibility makes technology usable for SWDs, *accessibility does not guarantee that SWDs will be able to learn with the technology*. Conversely, the flexible learning environments and curriculum enhancements described in the educational framework Universal Design for Learning do not ensure the technology will be accessible (Rose et al., 2005; Shaheen & Lohnes Watulak, 2019).

With accessibility and curriculum on separate islands, learning technology struggles to meet the needs of SWDs. This is increasingly concerning considering the mass-disabling event, COVID-19. An estimated 45% of COVID-19 survivors globally, regardless of hospitalization status, experience a “heterogeneous range of common ongoing symptoms”, which include cognitive impairments to working memory, executive functioning, and concentration (Cui et al., 2024; O’Mahoney et al., 2023). These symptoms are not solely exclusive to teachers, students, and researchers who care about the design of learning technology. We all can be affected. Despite the decrease in public school enrollment, the demand for special education services has increased each year (National Center for Education Statistics, 2023). Researchers across accessibility and learning science urgently need to unite, not only for SWDs and their teachers, but for us. We need systems of support so we can continue to innovate during a global health emergency where disability can impact any of us, at any time.

Intended audience and number of participants

We are seeking participants with interest and/or experience in accessible educational practices and/or educational technology. The ideal participant would have interest in both areas. Substantial experience is not required. People with interest and/or experience in only one of the two areas, who are open to building bridges with the other area are welcome. We aim for our workshop to reflect a variety of perspectives across the learning science community. We hope for there to be representation from those whose primary expertise/research interest is in design and system building of educational technologies, as well as those with a research focus on students with disabilities, and those whose interests center primarily in pedagogical applications of learning science. Should the number of applicants exceed our workshop’s capacity, preference will be given to those whose research interests fall under an intersection of multiple of our workshop themes (e.g. accessibility and educational technology). We envision this workshop will have at least fifteen participants and no more than thirty.

Event duration and format

This workshop will be a full day in-person event, with the ability to transition fully virtual. Online-only participants will join the session via Zoom, using the Breakout Rooms during the smaller group discussions. For a hybrid event, each group discussion will have a laptop where virtual participants can Zoom in. In the event of a virtual only workshop, all participants will be assigned a group using Zoom’s Breakout Room feature.

Outline of planned activities

Morning Session (210 minutes/ 3.5 hours)

1. Welcome (5 minutes): Organizers provide overview of workshop goals and activities.
2. Lightning talks (30 minutes): Participants will introduce themselves, their work, or their position papers.
3. Keynote with Q&A (35 minutes): “What do we mean by accessibility?” An invited speaker will discuss critical issues, emerging areas, and broader applications of accessibility.
4. Break (10 minutes)
5. Collaborative mapping activity and small group discussion (60 minutes): Participants will join break out groups to discuss challenges and opportunities for accessible learning technology. Discussions will be visually documented on a digital collaborative tool (e.g. Miro).
6. Break (10 minutes)
7. Plenary discussion (60 minutes): Participants reconvene to share discussion insights and visualizations from the smaller discussion groups.

Extended Break (60 minutes/1 hour)

Afternoon Session (210 minutes/3.5 hours)

1. Manifesto drafting and small group discussion (90 minutes): Participants will use a collaborative authoring tool (e.g. Google Docs) to draft a living document of accessibility values and principles to incorporate in their research practices and lab culture. The manifesto drafts are inspired by datapractices.org and the Global Data Ethics Pledge’s initiative to create community principles for ethical data sharing, which can be found here: <https://datapractices.org/manifesto/>.
2. Break (20 minutes)



3. Plenary discussion (90 minutes): Participants reconvene to share their draft manifestos from the smaller discussion groups. Group manifestos will be discussed and compiled into a joint document that will be shared online post-workshop.
4. Closing Remarks (10 minutes): Organizers will synthesize primary takeaways from discussion, identify next steps for building a stronger community on accessible learning technology, and open a post-workshop Discord server and mailing list for all to join.

Expected outcomes and contributions

The expected outcomes of the workshop are as follows:

1. A collective understanding of emerging areas within accessible learning technology.
2. A joint statement of accessibility values and principles.
3. A repository of resources informed by workshop contributions and discussions.
4. An ongoing community via Discord and a mailing list to facilitate post-workshop collaborations.

Facilities and equipment required

To facilitate inclusion for those with disabilities, Live Captioning services are needed. Otter.Ai is a tool we recommend because it supports virtual, in-person, and hybrid modalities. Additionally, it can be accessed by participants on individual devices.

About the organizers

The organizers of this workshop have interdisciplinary research backgrounds across learning science, social computing, Human-AI interaction, and accessibility. Naomie is a disabled, Ph.D. student in Carnegie Mellon University's Human-Computer Interaction Institute (HCII). She was an accessibility researcher at Microsoft and Apple AI/ML, prior to joining the HCII. Naomie has co-authored and taught STEM curriculum in Special Education. Margaret Ellen is a disabled, undergraduate student studying computer science and sociology at Grinnell College. She has experience developing accessible interfaces with the University of Washington's Make4All Lab. Margaret Ellen also works part time at her college's Disability Resource Center creating accessible educational programming. Mia is an undergraduate student at Haverford College studying computer science and visual studies. They are a student-activist supporting Haverford College's Disability Advocacy Group. Mia redesigned and co-taught the Introduction to Computer Science curriculum for their college. Haiyi Zhu is an Associate Professor in Carnegie Mellon University's Human-Computer Interaction Institute, where she directs the Social AI Lab. She is a social computing researcher exploring the intersection of human-computer interaction, machine learning, and social psychology. Vincent Aleven is a Professor in Carnegie Mellon University's Human-Computer Interaction Institute, where he directs the Creating Adaptive Tutoring Systems (CATS) Lab. He examines how people interact and learn with adaptive, AI-based learning technologies, and to advance the design and engineering of these technologies.

Relationship to previous events

The workshop in this proposal seeks to bring awareness to an underrepresented area at ISLS. In 2022, ISLS hosted several workshops that brought interdisciplinary scholars together to consider marginalized groups in their research practices: 1) Technology in the margins: Queer and trans technologies to support reorienting toward LGBTQ2S+ solidarity (Paré et al., 2022), 2) AI and educational policy (Friedman et al., 2022) and 3) Centering of Living, Mattering of Lives: Methodological and Transformative Possibilities for Socially Just STEM Education Research (El Halwany et al., 2022). Our workshop also seeks to center social justice in the design, development, and evaluation of educational technology and learning science research.

Participant requirements and solicitation plan

Participant solicitation

We will solicit participation using social media, mailing lists, and connecting with prior ISLS attendees. Participants will be asked to contribute a statement of interest for the workshop. Submissions can take several forms, including: 1) A short biography with a statement of motivation/interest, 2) a two-page position paper discussing one or more themes highlighted in this proposal, 3) a case study discussing ongoing work in learning technology, accessibility, or special education, or 4) other formats with content related to the workshop themes.



Each submission will be reviewed by two organizers and accepted based on quality of the submission and diversity of perspectives to allow for a meaningful exchange of knowledge.

Draft call

We invite leading and emergent scholars in learning science, special education, and accessibility who are interested in and/or working on designing accessible technology for students with disabilities to join us at ISLS 2024. In this full-day workshop, participants will explore inclusive education and disability frameworks to create more accessible learning technology, research practices, and lab cultures. We aim to bring together a diverse community of researchers across several disciplines, including K-16 educators and industry professionals.

References

Cui, R., Gao, B., Ge, R., Li, M., Li, M., Lu, X., & Jiang, S. (2024). The effects of COVID-19 infection on working memory: a systematic review. *Current Medical Research and Opinion*, 40(2), 1–11.

El Halwany, S., Adams, J., Marlow, S., Qureshi, N., Prieto, M., Turner, K., Paton, C., & Edino, R. (2022). Centering of Living, Mattering of Lives: Methodological and Transformative Possibilities for Socially Just STEM Education Research. *International Collaboration toward Educational Innovation for All*, 2022-June, 117–120.

Friedman, L., Dragnić-Cindrić, D., Chang, M. A., Pakhira, D., Fusco, J., Walker, E., & Roschelle, J. (2022). ISLS'22 Workshop: AI and Educational Policy. *International Collaboration toward Educational Innovation for All*, 2022-June, 110–112. <https://par.nsf.gov/servlets/purl/10336490>

Fryia, G. D., Wachowiak-Smolikova, R., & Wachowiak, M. P. (2009). Web accessibility in the development of an e-Learning system for individuals with cognitive and learning disabilities. *2009 First International Conference on Networked Digital Technologies*. <https://doi.org/10.1109/ndt.2009.5272167>

Jackson, V. L. (2003). Technology and Special Education: Bridging the Most Recent Digital Divide. *ERIC*.

National Center for Education Statistics. (2023, May). *Students with disabilities*. Nces.ed.gov.

O'Mahoney, L. L., Routen, A., Gillies, C., Ekezie, W., Welford, A., Zhang, A., Karamchandani, U., Simms-Williams, N., Cassambai, S., Ardashvili, A., Wilkinson, T. J., Hawthorne, G., Curtis, F., Kingsnorth, A. P., Almaqhami, A., Ward, T., Ayoubkhani, D., Banerjee, A., Calvert, M., & Shafran, R. (2023). The prevalence and long-term health effects of Long Covid among hospitalised and non-hospitalised populations: A systematic review and meta-analysis. *EClinicalMedicine*, 55, 101762. <https://doi.org/10.1016/j.eclim.2022.101762>

Paré, D., Windsor, S., & Craig, J. (2022). Technology in the margins: 2nd Annual Meeting of the International Society of the Learning Sciences, ISLS 2022. *International Collaboration toward Educational Innovation for All*, 2022-June, 106–109. <https://pure.psu.edu/en/publications/technology-in-the-margins-queer-and-trans-technologies-to-support>

Rose, D. H., Meyer, A., & Hitchcock, C. (2005). *The universally designed classroom : accessible curriculum and digital technologies*. Harvard Education Press. <https://eric.ed.gov/?id=ED568861>

Shaheen, N. L., & Lohnes Watulak, S. (2019). Bringing Disability Into the Discussion: Examining Technology Accessibility as An Equity Concern in the Field of Instructional Technology. *Journal of Research on Technology in Education*, 51(2), 187–201. <https://doi.org/10.1080/15391523.2019.1566037>

United Nations Children's Fund (2021). Seen, Counted, Included: Using Data to Shed Light on the Well-Being of Children with Disabilities. *UNICEF*. <https://data.unicef.org/resources/children-with-disabilities-report-2021/>

U.S. Department of Justice, Civil Rights Division & U.S. Department of Education, Office for Civil Rights. (2010). Joint Dear Colleague Letter: Electronic book readers by T. E. Perez and R. Ali. Retrieved from the Department of Education website <https://www2.ed.gov/about/offices/list/ocr/letters/colleague-20100629.html>

World Health Organization. (2023, March 7). *Disability and Health*. WHO; World Health Organization: WHO. <https://www.who.int/news-room/fact-sheets/detail/disability-and-health>

Xie, J., Basham, J. D., Marino, M. T., & Rice, M. F. (2017). Reviewing Research on Mobile Learning in K–12 Educational Settings. *Journal of Special Education Technology*, 33(1), 27–39. <https://doi.org/10.1177/0162643417732292>

Acknowledgments

This work is supported by the National Science Foundation grant awards: #DGE1745016 and #DGE2140739.



Knowledge Building and Generative AI to Advance Community Knowledge

Lydia Cao, Marlene Scardamalia, Carl Bereiter, Stacy Costa,
Monica Resendes, Dina Soliman, Ahmad Khanlari, Boris Steipe
ly.cao@utoronto.ca, marlene.scardamalia@utoronto.ca, carl.bereiter@utoronto.ca,
stacy.costa@mail.utoronto.ca, monica.resendes@utoronto.ca,
dinaa.soliman@utoronto.ca, a.khanlari@mail.utoronto.ca, boris.steipe@utoronto.ca
University of Toronto

Jianwei Zhang, University of Albany, jzhang1@albany.edu
Mei-Hwa Che, University of Albany, mchen@albany.edu
Bodong Chen, University of Pennsylvania, cbd@upenn.edu
Thérèse Laferrière, Laval University, Therese.Laferriere@fse.ulaval.ca
Yuqin Yang, Central China Normal University, yuqinyang0904@gmail.com
Carol K.K. Chan, University of Hong Kong, ckkchan@hkucc.hku.hk
Gaoxia Zhu, National Institute of Education, Singapore, gaoxia.zhu@nie.edu.sg
Chew Lee Teo, National Institute of Education, Singapore, chewlee.teo@nie.edu.sg
Fernando Castillo, Gimnasio La Montaña, fernandodiazdelcastillo@glm.edu.co
Preeti Raman, Toronto Metropolitan University, praman@torontomu.ca
Linda Massey, Principal Association Projects, lmassey@principals.on.ca

Abstract: Generative Artificial Intelligence (GenAI) promises to change the landscape of education, yet its use for personalization and individual learning may perpetuate outdated 'learning as acquisition' and 'mind as container' models of education. This workshop will explore uses of GenAI to advance collective intelligence and community knowledge. Participants from diverse backgrounds will explore models of use from knowledge building principles; for example, reconstruction of community knowledge from multiple perspectives, visualisation of idea evolution, rise above on divergent ideas, text-image idea transformations, self-organization around knowledge advancement. The overarching goal will be a roadmap to theoretical, technological, infrastructural, and ethical advancements in use of GenAI for KB.

Organizers' background

Lydia Cao is a Postdoctoral Fellow at the University of Toronto, a learning scientist with focus on design, emerging technology, sustainability, and AI. Marlene Scardamalia, Distinguished Professor of Knowledge Innovation & Technology, along with Carl Bereiter, Professor Emeritus, both at the University of Toronto, developed Knowledge Building, and CSILE, the first networked system for collaborative learning and successor, Knowledge Forum® used in innovative applications worldwide at all educational levels. Jianwei Zhang is a Professor at the School of Education, University at Albany, specializing in collaborative learning and Knowledge Building across communities supported by new technology. Mei-Hwa F. Chen is an Associate Professor, Department of Computer Science, University at Albany, specializing in data structures and software engineering. Bodong Chen is an Associate Professor in Learning Sciences and Technologies at the University of Pennsylvania, directing the Wonder Lab and the Penn Knowledge Building Innovation Network, with specialization in learning analytics and network science. Thérèse Laferrière is Professor of Pedagogy at l'Université Laval, architect of the Networked Remote School initiative and network-enabled Knowledge Building communities. Carol K. K. Chan is an Honorary Professor at the Faculty of Education, University of Hong Kong, specializing in Knowledge Building to advance student capacity for knowledge creation and innovation. Gaoxia Zhu is an Assistant Professor in the Learning Sciences and Assessment Academic Group focusing on understanding students' social, cognitive, and emotional patterns during Knowledge Building using multimodal data sources. Chew Lee Teo is a Senior Research Scientist and Deputy Director of the Centre for Research in Pedagogy and Practice at the Office of Education Research, National Institute of Education (NIE) and founder of the Knowledge Building Community - Singapore and International Knowledge Building Community Network Learning (KBC-NL). Linda Massey is



Associate Director of Principal Association Projects, Ontario Principals' Council, and Coordinator of *Knowledge Building Connects*. Preeti Raman, Assistant Professor, Department of Computer Science of Toronto Metropolitan University, specializes in AI in Education, Computer Supported Collaborative Learning, and Caring Pedagogies. Kate Budd is a teacher and PhD student at Toronto District School Board and University of Toronto specializing in design thinking, elementary literacy, and Knowledge Building. Stacy Costa is a PhD student at University of Toronto specializing in Engineering Education, student reasoning, and Transactivity. Ahmad Khanlari is a Postdoctoral Fellow at University of Toronto, specializing in learning analytics, natural language processing, and social network analysis. Monica Resendes is Program Manager at Institute for Knowledge Innovation Technology (IKIT) specializing in professional development, formative assessments, and Knowledge Building analytics. Dina Soliman is a PhD student at University of Toronto specializing in systems thinking and computational thinking. Boris Steipe is a Professor emeritus of computational biology at the University of Toronto, and the founder of the "Sentient Syllabus" project, focused on new directions of academia in the era of generative AI.

Intended audience

This full day workshop is intended for researchers of the learning sciences, CSCL, organisational psychologists, computer scientists from various disciplinary backgrounds and theoretical traditions, education practitioners, designers of learning analytics, and policymakers with interests in designing AI for Knowledge Building.

Description of the event

Theme and goals

Generative Artificial Intelligence (GenAI) is changing the landscape of education. However, much of its use is geared towards personalization and individual learning (Bond et al., 2024). While students can benefit from personalized learning experiences, it is important to be wary of the extent to which personalization reinforces the 'learning as acquisition' and 'mind as container' paradigms in education (Bereiter, 2002). Education researchers have expressed concerns that a narrow focus on AI applications will result in "a type of digital duct tape to hold together an obsolete industrial-era educational system, automating outdated instruction and assessment" (Dede, 2023, p. 35). Furthermore, the focus on individualization and personalization potentially reinforces the already prevalent individualism and isolation in our society, which is taking a toll on the mental health and wellbeing of young adults (Weissbourd et al., 2023).

Sharples (2023) proposed a vision of Social Generative AI and took the view of extended cognition (Clark & Chalmers, 1998), seeing cognition as shared between humans and AI and positioning AI as a "participant in the conversations for learning" (p. 161). AI has been incorporated into a learning environment to facilitate social-collaborative learning (e.g., Cobi, ISAT, Narrative AI). Designing AI for Knowledge Building (KB) additionally requires participants to intentionally sustain and advance community knowledge for public good. Research within organizational behaviour and management has explored AI integration to enhance collective intelligence. Woolley and colleagues (2023) outlined three cognitive functions where AI potentially can be helpful: Transactive Memory Systems (TMS), for distributing and coordinating team knowledge; Transactive Attention Systems (TAS), for managing team focus and attention; and Transitive Reasoning Systems (TRS), for synthesizing team reasoning in complex decision-making. They proposed that AI can enhance these systems by identifying important patterns and trends, managing distractions, and providing decision support.

Current research has concentrated more on access to and coordination of available knowledge than on knowledge creation informed by theories and processes that sustain knowledge-creating communities. In this workshop, we aim to shift focus from personalization and organisational behaviour research to uses of GenAI to advance community knowledge. We aim to address this gap in the GenAI landscape by bringing researchers, educators, designers, engineers, practitioners, and policymakers across disciplines and backgrounds to discuss this challenge from multiple perspectives:

Theoretical: What is the epistemological and ontological status of AI in KB?

Design: In what ways can AI support work in design mode to maximize a group's potential for creativity and knowledge creation?

Infrastructural: In what ways can AI become functional infrastructure for Knowledge Building?

Ethical: What ethical considerations need to be addressed when integrating AI in Knowledge Building?

Theoretical background and relevance to field and conference

Knowledge Building (KB) theory, practices, and technology focus on collective responsibility for advancing the state of community knowledge (Scardamalia & Bereiter, 2014). KB has its roots in the nature of expertise,



progressive problem solving, intentional learning, creativity, and knowledge creation, with extensive research spanning four decades (Chen & Hong, 2016). Unlike learning, which primarily involves acquiring existing knowledge, KB emphasizes the collective effort to advance the state of community knowledge. Knowledge is viewed as improvable, advanced in 'design mode' through iteratively improving ideas, beyond 'belief mode' that focuses on accepting, rejecting, or evaluating claims to reach conclusions. Knowledge is made public, to be improved through collective effort; this requires going beyond individual mental representations and knowledge as individual possession. Learning, or individual achievement, can advance throughout school years without leading to KB; in contrast, KB has learning as a byproduct (Scardamalia, 2002). KB as conceptualized by Scardamalia and Bereiter (2014), is principles-based rather than following a set of predetermined paths to instructional goals or prescribed procedures. KB is emergent and relies on self-organisation - teachers and students collaboratively shaping the course of inquiry, research, and knowledge advancement as it unfolds, actively monitoring progress, and identifying emergent goals. Scardamalia and Bereiter (2014) have discussed distinctions between shallow and deep constructivism to distinguish modern constructivist learning models such as inquiry, discovery, and project-based learning from knowledge-creating communities. Central to KB is a commitment to making ideas public, continuously contributing, and building on, as well as 'rising above' ideas to generate new insights. KB communities focus on creation and advancement of knowledge, enabling students to contribute to the local community through means extensible to the global community of knowledge creators.

Knowledge Forum is an online environment specifically designed for KB (Scardamalia & Bereiter, 2014). Incorporating GenAI as a technology into Knowledge Forum has the potential to enhance KB aligned with the KB principles such as idea diversity, democratizing knowledge, and symmetric knowledge advancement. Means for enhancing KB with GenAI have been discussed previously during Knowledge Building Connects meetings, which are monthly gatherings for people interested in KB to share and advance theory, technology, and practice of KB. Promising ideas include: 1) Community knowledge reconstructed through multiple lenses and summaries to facilitate discourse regarding the state of community knowledge and cross-community collaboration; 2) Visualisation of idea evolution in collective discourse; 3) Cross-modality idea capture with voice recognition; 4) Highlight divergent ideas to 'rise above'; 5) Adaptive presentation of authoritative knowledge sources; and 6) interfacing students' group dialogues with AI partners.

Outline of planned activity

Before the Conference - Monthly meetings: These meetings will spotlight specific projects or research areas within AI, aiming to maximize idea diversity within the community. Each session will delve into one project or research area, utilizing the five guiding questions as a framework for discussion.

During the Conference- Lightning Talks: These sessions will facilitate the sharing of various projects at the intersection of KB and AI, which will serve as boundary objects for further improvement and stimulating idea generation for the wider community. Projects include but not limited to:

1. Developing AI-empowered analytics for Knowledge Building (Jianwei Zhang, Mei-Hwa Chen, Bodong Chen, Preeti Raman)
2. Collabot: Can AI help students to improve their ideas? (Thérèse Laferrière)
3. Exploring the role of AI in Knowledge Building from Elementary to Higher Education, with focus on depth of understanding and work in design mode (Yuqin Yang, Carol Chan, Kate Budd, Monica Resendes, Dina Soliman)
4. Investigating students' reliance on AI in Knowledge Building (Gaoxia Zhu, Chew Lee Teo)
5. Integrating Generative AI with Knowledge Building: Teachers' and Principals' Perspectives (Kate Budd, Fernando Castillo, Linda Massey)
6. Report Cards reimagined for Knowledge Building (Kate Budd, Stacy Costa, Ahmad Khanlari)
7. Fostering self-organization for knowledge advancement (Carl Bereiter, Marlene Scardamalia, Boris Steipe)

Working Groups: Participants will choose one working group (theoretical, infrastructural, technological, or ethical perspectives). The boundary objects will serve as stimulus for group discussion and idea generation. Each group will dedicate 2-3 hours to make progress in their chosen area.

Plenary: Each group will present a summary of their discussions and outcomes. The whole group will reflect on the progress made and consolidate future directions.

After the Conference - monthly meetings: These meetings will continue momentum from the workshop. Meeting schedules will be flexible, accommodating availability, and interest.



Expected outcomes and contributions

The workshop aims to formulate directions and a roadmap for designing GenAI for KB from perspectives of theory, technology, infrastructure, and ethics. We anticipate that the sustained efforts will culminate in the publication of a theoretical paper. Furthermore, we foresee that the insights gained from the workshop will steer a series of empirical research that will shed light on the overarching questions.

Participation

We anticipate 15-25 participants for this workshop during the conference. The participants will include both presenters and non-presenters. To solicit participants, we will post announcements on our website and social media. We will also reach out directly to people in the international KB network.

Relationship to similar events conducted in the past

This workshop builds upon the themes and threads explored in the previous workshop (Hod et al., 2022) and symposium on infrastructure (Chen et al., 2023) at the ISLS conferences in 2022 and 2023.

Facilities and equipment required

During the conference, we would like to request a room that supports hybrid modalities for participants to join remotely and with a projector and roundtables or small groups to work.

References

Bereiter, C. (2002). *Education and Mind in the Knowledge Age*. Routledge.

Bereiter, C., & Scardamalia, M. (2014). Knowledge Building and Knowledge Creation: One Concept, Two Hills to Climb. In S. C. Tan, H. J. So, & J. Yeo (Eds.), *Knowledge Creation in Education* (pp. 35–52). Springer Singapore. https://doi.org/10.1007/978-981-287-047-6_3

Bond, M., Khosravi, H., De Laat, M., Bergdahl, N., Negrea, V., Oxley, E., Pham, P., Chong, S. W., & Siemens, G. (2024). A meta systematic review of artificial intelligence in higher education: A call for increased ethics, collaboration, and rigour. *International Journal of Educational Technology in Higher Education*, 21(1), 4.

Chen, B., & Hong, H.-Y. (2016). Schools as Knowledge-Building Organizations: Thirty Years of Design Research. *Educational Psychologist*, 51(2), 266–288. <https://doi.org/10.1080/00461520.2016.1175306>

Chen, B., Scardamalia, M., Bereiter, C., Zhang, J., Park, H., Teo, C. L., Yuan, G., Lee, A. V., Hod, Y., Kashi, S., Cohen, E., Oshima, J., Oshima, R., Kawakubo, A. J., Kayagi, T., Yamashita, S., Kumazawa, R., Lu, J., Chan, C. K., ... Bielaczyc, K. (2023). Infrastructuring for Knowledge Building. In C. Damşa, M. Borge, E. Koh, & M. Worsley (Eds.), *Proceedings of the 16th International Conference on Computer-Supported Collaborative Learning—CSCL 2023* (pp. 327–336). International Society of the Learning Sciences.

Clark, A., & Chalmers, D. (1998). The Extended Mind. *Analysis*, 58(1), 7–19.

Dede, C. (2023, August 6). What is Academic Integrity in the Era of Generative Artificial intelligence? *Silver Lining for Learning*. <https://silverliningforlearning.org/what-is-academic-integrity-in-the-era-of-generative-artificial-intelligence/>

Hod, Y., Chen, B., Cohen, E., Kashi, S., Yuan, G., & Lee, A. (2022). Infrastructuring for Knowledge Building: 2nd Annual Meeting of the International Society of the Learning Sciences, ISLS 2022. *International Collaboration toward Educational Innovation for All*, 94–97.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Open Court.

Scardamalia, M., & Bereiter, C. (2014). Knowledge Building and Knowledge Creation: Theory, Pedagogy, and Technology. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (2nd ed., pp. 397–417). Cambridge University Press. <https://doi.org/10.1017/CBO9781139519526.025>

Sharples, M. (2023). Towards social generative AI for education: Theory, practices and ethics. *Learning: Research and Practice*, 9(2), 159–167. <https://doi.org/10.1080/23735082.2023.2261131>

Weissbourd, R., Batanova, M., McIntyre, Joseph, Torres, Eric, Irving, Shanae, Eskander, Sawsan, & Bhai, Kiran. (2023). *On Edge: Understanding and Preventing Young Adults' Mental Health Challenges*.

Woolley, A. W., Gupta, P., & Glikson, E. (2023). Using AI to enhance collective intelligence in virtual teams: Augmenting cognition with technology to help teams adapt to complexity. In L. Gilson, T. O'Neill, & M. Maynard (Eds.), *Handbook of Virtual Work* (pp. 67–88). Edward Elgar Publishing.



Designing for Powerful Ideas in Educational Robotics in the Era of AI

Walter Akio Goya, Jonathan Pang, Paulo Blikstein, Leah F. Rosenbaum
aag2197@tc.columbia.edu, jep2211@tc.columbia.edu, paulob@tc.columbia.edu, leah@tlrlab.org
Teachers College, Columbia University

Arnan Sipitakiat, Peeranut Pongpakatien
arnan.s@cmu.ac.th, peeranut.ppkt@gmail.com
Chiang Mai University

Abstract: In this half-day workshop, participants will interact with the latest iteration of the GoGo Board platform for educational robotics, which incorporates new features for data logging, internet of things (IoT) and remote communication as well as artificial intelligence (AI) integrations. Beyond exploring the GoGo Board's features, participants will examine the platform as a design case study, examining the learning sciences principles underpinning its hardware and software. Participants will, in turn, be able to extend these theoretical and design lenses to the educational technologies that they are researching and developing.

Proposers/Organizers

Akio Goya

Akio is an Educational Technology Designer for the Transformative Learning Technologies Lab, coordinating the design, implementation, and documentation of GoGo Boards in Brazil, as well as the implementation of makerspaces in public schools. Akio holds a Master's degree in Instructional Technology and Media from Teachers College, Columbia University (USA) and a Master's and a Bachelor's degree in Computer Engineering from University of São Paulo (Brazil), and a Teacher Licensure in Mathematics (Middle and High School) from FIAR (Brazil).

Jonathan Pang

Jonathan is a Program Manager with the Transformative Learning Technologies Lab at Teachers College, Columbia University. He has led workshops with the GoGo Board across various contexts including teacher professional development programs, graduate coursework, and K-12 classroom environments. Jonathan earned his master's and bachelor's degrees in mechanical engineering from Stanford University.

Paulo Blikstein

Paulo Blikstein is an Associate Professor at Teachers College and an Affiliate Associate Professor of Computer Science at Columbia University, where he directs the Transformative Learning Technologies Lab and the Lemann Center for Brazilian Studies. His research focuses on how new technologies can transform the learning of science, engineering and computation. Paulo is the co-inventor of the GoGo Board, co-leading its research and development since 2001. Paulo has a Ph.D. from Northwestern University, a MSc. from the MIT Media Lab and an M.Eng. and B.Eng. from the University of São Paulo, Brazil.

Leah Rosenbaum

Leah is an Associate Research Scientist with the Transformative Learning Technologies Lab. In collaboration with the New York Hall of Science, she organizes an NSF-funded research and implementation project in which middle school students use GoGo Boards to collect data and create visualizations to answer questions they have posed about their neighborhoods and communities. Leah earned her PhD in the Learning Sciences and Human Development from UC Berkeley and her Bachelor's in Mathematics from Scripps College.

Arnan (Roger) Sipitakiat

Arnan (Roger) directs the Teaching and Learning Innovation Center (TLIC) at Chiang Mai University in Thailand. As a faculty and researcher at the Computer Engineering Department, he also directs the Learning Inventions Laboratory (LIL). Arnan is the co-inventor of the GoGo Board, co-leading research and development on the



toolkit since 2001. Arnan focuses on designing technologically-rich learning tools, such as the GoGo Board, that have allowed students to explore areas including robotics, interactive art, games, agriculture, and community development. Arnan earned his MSc. and Ph.D. from the Massachusetts Institute of Technology and B.Eng. from Chiang Mai University.

Peeranut Pongpakatien

Peeranut is an engineer and learning technologies designer based in Chiang Mai, Thailand. During his graduate studies in the Learning Inventions Lab, Peeranut led the technical development of the GoGo Board 6, facilitating workshops and courses across Thailand and supporting remote workshops worldwide. Peeranut earned his master's and bachelor's in computer engineering from Chiang Mai University.

Intended audience

This workshop is intended for graduate students and researchers interested in exploring design tools and frameworks to use in their learning technology design and research. More broadly, it is open to all researchers, designers, and educators interested in exploring powerful ideas in robotics, data, and artificial intelligence through hands-on experimentation. (Note that the GoGo Board is an open-source platform.)

Duration of the event

Half-day (3-4 hours, flexible depending on conference scheduling demands).

Description of the event

The Gogo Board was invented in 2001 as a low-cost and learner-friendly robotics and scientific sensing platform. In the years since the project has undergone several design iterations—each affording new possibilities for students across a diverse range of ages and backgrounds to explore powerful ideas in computing and STEM. In this workshop, participants will interact with the GoGo Board Kit version 6, which incorporates new features for data logging, internet of things (IoT) and remote communication, and artificial intelligence (AI) integrations. Beyond exploring the GoGo Board's features, participants will examine the principles underpinning its hardware and software design, such as selective exposure, blackboxing, glassboxing, and authentic science and engineering practices [1-3].

The workshop will be divided into six activities:

1. **A brief historical discussion** about the design of tangible interfaces in the Learning Sciences and in the Interaction for Children communities, as a way to frame the design lessons of the workshop.
2. **A quick exploration of the basic features** of the GoGo 6, always in connection with the research data and design decisions that generated each feature. Participants will use onboard controls to immediately display sensor values and power motors out of the box and without programming, before finally connecting to a computer to explore the GoGo software platform for coding and data visualization. During this activity, the facilitators will continuously make connections between the different features and the design principles that inspired them.
3. **Experimentation with advanced features:** Participants will follow a streamlined process for configuring remote control and communication between GoGo boards and other IoT platforms, allowing users to create remote robotics labs and debug network communication. The facilitators will highlight features that are simplified (black-boxed) and maintained “complex” (glass-boxed) to scaffold students’ learning with the GoGo Board [3]. Again, facilitators connect features, research data, and design.
4. **Exploration of AI and data science functionalities:** Participants will have the opportunity to design their own implementations of AI and data science features into the platform. Participants will also critique the design and implementation of these features in the hardware and software platform.
5. **Conclusion and Gallery Walk:** Participants will discuss their projects, lessons learned, and do a final show-and-tell of what they produced during the workshop.
6. **Post-workshop:** We will collect optional participants’ information for post-workshop interactions, such as follow-up design discussions, new developments, and future collaborations.

Workshop facilitators will lead discussions between each section, inviting participants to critique the GoGo Board through various theoretical and design lenses, including selective exposure, glass/black-boxing, cultural forms,

and the salience of powerful ideas [1-3]. By the end of the half-day workshop, participants will be able to extend this approach beyond the GoGo Board and evaluate other education technologies along the same dimensions. We do not intend this to be a mere technical workshop on a given platform but a hands-on experience with a theory-informed platform for children, exemplifying how the platform evolved throughout 20 years of design-based research cycles--a pretty unique trajectory.

Participation requirements

No requirements. We invite to join all participants interested in tangible interface design, educational robotics, and data science, irrespective of skill or experience levels.

Relationship to similar events conducted in the past

The author team has recently conducted workshops featuring the GoGo Board at two conferences:

- Thailand Constructionism Forum 2024. January 20-21, 2024. Bangkok, Thailand.
- FabLearn / Constructionism 2023. October 8, 2023. New York City, United States.

Facilities and equipment required

Facilities:

- Projector / screen for workshop facilitators
- Wifi connectivity

Equipment:

- Gogo Boards Kits (board and sensors -- we will provide them)
- Participants will be asked to bring their laptops with an available USB-C port.

Minimal and maximal number of participants expected

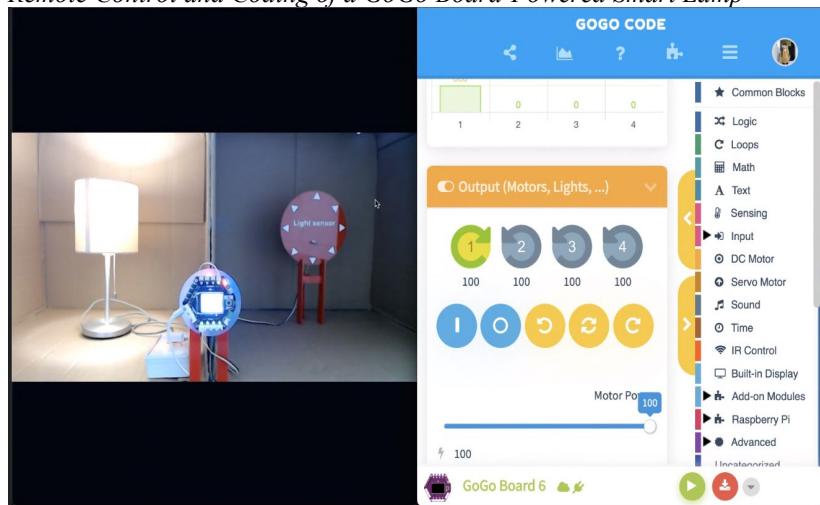
8 - 15 participants

Draft call for participation

Calling all researchers, designers, and educators interested in exploring powerful ideas in robotics, data, and artificial intelligence:

In this half-day workshop, you will interact with the latest iteration of the GoGo Board platform for educational robotics, which incorporates new features for data logging, internet of things (IoT) and remote communication as well as artificial intelligence (AI) integrations. Beyond exploring the GoGo Board's features, you will evaluate the platform as a design case study, examining the learning sciences principles underpinning its hardware and software. This is a unique case of an open-source robotics and data science toolkit informed by Learning Sciences and Design-Based Research over a period of 20 years! You will be able to extend these theoretical and design lenses to other educational technologies, including your own research and design projects.

Figure 1
Remote Control and Coding of a GoGo Board-Powered Smart Lamp





Workshop format

The workshop is intended to be conducted in-person but could allow hybrid participation if needed. Planned activities—even without unforeseen events—will include some remote facilitation by the international workshop team.

References

Blikstein, P. (2015). Computationally Enhanced Toolkits for Children: Historical Review and a Framework for Future Design. *Foundations and Trends in Human-Computer Interaction*, 9(1), 1–68.

Hmelo, C.E. and Guzdial, M. (1996). Of black and glass boxes: Scaffolding for doing and learning. *Proceedings of the 1996 international conference on Learning sciences (ICLS '96)*. International Society of the Learning Sciences, 128–134.

Resnick, M. and Silverman, B. (2005). Some reflections on designing construction kits for kids. *Proceedings of the 2005 conference on Interaction design and children (IDC '05)*. Association for Computing Machinery, New York, NY, USA, 117–122.



Reimagining and Advancing CSCL Research and Building CSCL Community

Carol Chan (organizer), University of Hong Kong, ckkchan@hku.hk
Michelle Lui (organizer), University of Toronto, michelle.lui@utoronto.ca
Jun Oshima, RECLS, Shizuoka University, joshima@inf.shizuoka.ac.jp
Bodong Chen, University of Pennsylvania, cbd@upenn.edu
Annelies Raes, KU Leuven University, annelies.raes@kuleuven.be
Wenli Chen, Nanyang Technological University, wenlichen@nie.edu.sg
Omid Noroozi, Wageningen University and Research, omid.noroozi@wur.nl

Abstract: Computer-Supported Collaborative Learning (CSCL) is at an important juncture with a rapidly changing research landscape—from technological advances, an increasingly diverse set of methods, and the emergence of related fields investigating social interactions. The workshop aims to: 1) examine the evolving understanding of CSCL as a maturing field and expanding scope of CSCL research, 2) examine new methodologies for CSCL researchers to analyze collaborative interactions, 3) consider CSCL research at the intersection of emerging related disciplines studying social interactions, 4) expand the scope of technologies beyond "computers" and analyze the intersection of CSCL and emerging technologies like AI, machine learning, and educational data analysis, 5) cultivate a robust, interconnected CSCL community that thrives on both diversity and unity, and 6) reflect on highlights, challenges and opportunities facing CSCL – how tensions are tackled and where we are going and charting visions and research directions.

Organizing team

We are a group of Computer-Supported Collaborative Learning (CSCL) researchers with shared interests in advancing Computer Supported Collaborative Learning research and building the CSCL community. We are interested in identifying and expanding the scope of CSCL research as well as invigorating the CSCL community through collaborative research and community networking. Carol Chan conducts research on knowledge building focusing on socio-cognitive-epistemic dynamics, reflective assessment, meta-discourse, analytics, and teacher professional development. Michelle Lui conducts research on collaborative inquiry with immersive environments—Both co-chairs of the CSCL Community Committee of ISLS. Jun Oshima conducts research on knowledge building curriculum and project-based learning using Knowledge Forum and knowledge-building analytics. Bodong Chen works on designing technological support for knowledge building, analyzing collaborative discourse using varied computational methods, also integrating generative AI to augment knowledge building. Annelies Raes conducts research on Computer-Supported Collaborative Problem Solving in secondary and higher education contexts, examining the orchestration of hybrid CSCL for both onsite and remote students. Wenli Chen conducts research designing technology and pedagogy for CSCL in authentic classrooms and learning analytics in CSCL. Omid Noroozi conducts empirical research on CSCL environments, examining different effects of variables in various CSCL settings, including problem-solving, domain-specific learning, and argumentative knowledge construction.

Intended audience

This workshop is intended for:

- learning scientists who currently conduct CSCL research; interested in building CSCL community
- scholars and researchers interested in technologies for supporting collaborative learning activities
- graduate students and early career scholars developing their careers in CSCL
- scholars and researchers in related communities (CSCW, learning analytics) with common interests in collaboration and technology for exchange

Participation is not limited by existing experience with CSCL research, as the goal is to broaden and strengthen the community of CSCL researchers.

Duration

A half-day workshop will be conducted as a hybrid synchronous event, with dedicated facilitation by in-person and remote organizers connected by Zoom and online sharing tools. Participants may register to attend as co-



located and virtual attendees. In addition, this workshop is augmented with activities throughout the conference period to reflect on learnings and to strengthen bonds and ties created during the workshop event.

Workshop description and goals

The field of CSCL is now at a pivotal juncture as we grapple with the advent of new paradigms and methods in the research landscape — from changing epistemologies and new design science to big data and artificial intelligence (e.g., generative AI, such as chatGPT), learning analytics, and burgeoning related ‘sister’ communities studying interactions amongst learners. The proposed half-day workshop aims to provide a platform that supports participants in critically reflecting, examining and expanding the boundaries of CSCL and to dialogue about the advances, challenges, and future of CSCL. Specifically, the workshop targets reimagining and advancing CSCL by identifying cross-disciplinary themes that resonate with CSCL research — particularly regarding emerging theories, methodologies, and technological innovation. We also aim to reflect and rethink our identity as CSCL researchers, consider current challenges and opportunities, and synergize our research efforts with advances in adjacent fields, thus reinforcing our strategic positioning and impacts across disciplines and strengthening the CSCL community.

Theoretical background and themes

This workshop stems from our interest in examining the theoretical underpinning of CSCL and how we can advance CSCL in light of changing epistemological, methodological, and technological contexts (Cress et al., 2021). The field of CSCL emerged in the early 1990s, seeking to understand collaboration as fundamental to human cognition, examining the interweaving of social interactions with artifacts for meaning-making (Luvidgen & Steier, 2019). CSCL research has made important advances in the last three decades, such as reframing the discourse of learning as knowledge co-construction, yet there are much-needed reflections concerning diversity, identity, and relationships with adjacent scholarly communities (Wise & Schwartz, 2017). Widespread changes in the post-Covid19 world, together with changes in epistemology, designs, analytics, and technology landscapes, further unveil pertinent questions, including the scope of interdisciplinary in CSCL, establishing the CSCL identity, and developing impacts of CSCL research on a global scale. As new technologies and methodologies emerge, revisiting the theoretical frameworks and conceptual tools that guide CSCL research and practice is imperative. The CSCL community needs to revisit our research advances, consider diverse frameworks and methods, grapple with tensions, and chart goals and directions forward. The CSCL community has been reflective (Cress & Rosé, ICLS 2016 workshop; Wise & Schwartz, 2017), and after several years, it is timely to reimagine and reflect on CSCL as we broaden our interdisciplinary scope to maintain a strategic presence within the evolving research and educational landscapes with the rise of hybridity.

The workshop aims to provide a platform for CSCL researchers to build knowledge collectively on the expanding nature and scope of CSCL research, working towards understanding cross-cutting themes with other related fields and reflecting on challenges with revolutionized technology (e.g., generative AI) and others as we chart future research directions. The following areas are possible themes of our exchange, inquiry and discourse:

- Expanding theories and epistemology: There is a need for CSCL researchers to consider diverse theoretical frameworks and epistemologies (Cress et al., 2021) rooted in multiple epistemic and system views (see related discussion in learning sciences, Fischer et al., 2018). CSCL also needs to be informed by design science, integration of generative AI and big data, social practice, and crossing over with related fields, reimagining collaborative learning in schools, workplaces, and diverse learning environments as new forms of creative collaboration emerge, adapting and formulating new models and frameworks.
- Methodological advances: Adopting new research methodologies for analyzing collaborative interactions is critical in the face of vast and complex datasets for analysis. Researchers have conducted careful analyses of CSCL methods (Jeong & Hmelo-Silver, 2016), and there are now varied, sophisticated data analyses, including network analysis, data mining, machine learning, etc., to glean meaningful insights from large-scale, multi-modal, and different kinds of data.
- New technologies and learning environment designs: CSCL research needs to consider incorporating state-of-the-art technological advances, such as AI, metaverse, analytics, and others, that can bring more personalized, adaptive, and scalable educational experiences in designing new environments. Learning analytics provides new technologies for understanding and enhancing collaborative interactions, such as using real-time feedback and further synergizing collaboration and analytics development.
- Equity: CSCL has the potential to address global educational disparities by fostering inclusive and culturally responsive CSCL environments and addressing student diversity and different student



populations (Yang et al., 2016). Outreach and collaboration with researchers and scholars from countries and educational systems that have limited access to resources and technology can bring out a more inclusive and diverse community that is beneficial for the advancement of CSCL.

- Research-practice partnership: CSCL research with multiple levels — large-scale implementation sustainability, scalability, and opportunities for educational change (Hod, Sagiv & Kali, 2018).
- Synergy and opportunities with related fields: CSCL research could work to identify cross-cutting themes of related research (CSCW, analytics, computer science) aligning with the broader educational, computational, and technology landscapes. Linking current research to new areas seeking intersection and synergy could help develop interdisciplinarity and broaden CSCL identity.

CSCL researchers have examined provocations in theories, agency, analyses, technology, scalability, and more (Wise & Schwartz, 2017). Provocations can be revisited to consider our research progress and new issues such as the use of AI, equity, and diversity issues. We seek to address the multifaceted tensions and possibilities, bringing together voices with diversity and unity, thereby strengthening the CSCL community.

Outline of planned activities (half-day workshop)

The workshop consists of activities aimed at sharing, gathering, and synthesizing participants' perspectives on CSCL research—the activities leading up to, distilled within the workshop, and during the conference period.

Before the Workshop

Participants will be encouraged to engage in preparatory activities to lay the groundwork for a productive workshop experience.

- Resource Materials: A curated list of articles/videos (NAPLeS) will be suggested for participants.
- Survey/Reflective responses. Attendees will be invited to submit brief responses outlining their research and visions for CSCL, such as how the field of CSCL animates their research and how they see the field evolving. Participants will take a survey and summarize their reflections to share with others in the workshop, and key themes will be identified.

During the Workshop

The workshop will be structured to maximize interaction, discussion, and collaborative ideation among participants, with the following planned activities:

- Introduction: A brief introductory presentation by the workshop co-organizers will serve to present aims, activities, and expected outcomes, followed by introductions of participants.
- Invited panel discussion: Approximately 5-6 prominent scholars in CSCL will be invited to address questions and elaborate on topics, such as: *What is CSCL research?* CSCL flash themes, research highlights, tensions, opportunities, and future directions; how can we support CSCL community building? Questions will be informed by asynchronous preparation before the workshop (e.g., survey, online discussion, and participant contributions).
- Breakout Sessions: Participants will work in groups to delve into specific CSCL areas and themes (listed above or others) linking to their research. They may introduce their reflections (pre-conference survey responses) to their teammates to share their backgrounds; each group is tasked with identifying advances and challenges and proposing directions. They will collate ideas on posters/ Padlet or Miro etc.
- Presentation: Groups from breakout sessions will share ideas, and the panel experts will offer comments with more participant feedback and interactions
- Next steps: Organizers will facilitate discussion and distill and recap learning from the day, with closing activities designed to foster networking and community building

After the Workshop

Continued activities during the conference will facilitate connections among participants and foster collaborations, including an open CSCL community committee meeting and the Meet the *ijCSCL* editors session.

Expected outcomes and contributions

The anticipated outcomes include a published summary of the discussions on the ISLS website. Expected outcomes include the initial establishment of a network for ongoing dialogue and collaboration within the CSCL community. We expect to have more insights into outreach and exchange with other communities.



Participation requirements

Applicants are required to complete a survey with reflective questions on CSCL to participate. The survey seeks to collect data about participants' experiences with CSCL and research focus; they will share their reflections about CSCL with participants to enrich the dialogue.

Relationship to similar events conducted in the past (e.g., CSCL or ICLS)

The proposed workshop is conceptually similar to a workshop held at ICLS 2016, *Towards Next Steps for the CSCL Community: Advancing Science and Informing real-world collaboration in Web 2.0*, organized by Ulrike Cress and Carolyn Rosé. The workshop focused on identifying cross-cutting themes in CSCL research related to Web 2.0 platforms and identifying a strategic position for CSCL research within the HCI and CSCW literature. The currently proposed workshop seeks to broaden the positioning of CSCL research across a wider intersection of collaborative technologies, new technologies and methods, and emerging practices of our community, as well as include new perspectives, opportunities, and challenges related to CSCL research.

Facilities and equipment required

We will use the official conference's communication platform to host remote workshop participants (e.g., Zoom). We will also use other tools, such as Miro (<https://miro.com/login/>) or Padlet (<https://padlet.com/>) to create a shared whiteboard for workshop activities. For on-site participants, the internet, projectors, and a room large enough to accommodate break-out spaces for theme group discussions are required.

Minimal and maximum number of participants

We aim to elicit participants between 15 and 25, with approximately even ratios of in-person and remote participants. We will also have the organizing team and invited experts as panel speakers.

Draft call for participation

About the Workshop: The field of Computer-Supported Collaborative Learning (CSCL) now stands at a pivotal juncture, navigating through the influx of new paradigms and methods in the research landscape — From evolving epistemologies to the integration of design science, big data, artificial intelligence (e.g., generative AI) and learning analytics, alongside burgeoning sister communities exploring interactions amongst learners, the CSCL field is facing tensions and opportunities. *Workshop Objectives:* This proposed workshop is dedicated to supporting participants in critically reflecting, examining, and exploring the boundaries of CSCL, building collective visions, and enriching their own research. We invite researchers, graduate students, and practitioners passionate about CSCL to participate in this dynamic workshop. Share your insights, engage in discussions, and contribute to shaping the future of CSCL research and community building. For more information and to register, please visit the conference website. We look forward to your active participation.

References

Cress, U., Rosé, C., Wise, A. F., & Oshima, J. (Eds.). (2021). *International handbook of computer-supported collaborative learning*. New York, NY: Springer.

Fischer, F., Goldman, S. R., Hmelo-Silver, C. E., & Reimann, P. (2018). Introduction: Evolution of research in learning sciences. In the *International handbook of the learning sciences*. Chicago, Routledge.

Heisawn Jeong & Cindy E. Hmelo-Silver (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help?, *Educational Psychologist*, 51 (2), 247-265.

Hod, Y. Sagy, O., & Kali, Y. (2018). The opportunities of networks of research-practice partnerships and why CSCL should not give up on large-scale educational change. *International Journal of Computer-Supported Collaborative Learning*, 13 (4), 457-466.

Ludvigsen, S. & Steier, R. (2019). Reflections and looking ahead for CSCL: Digital infrastructures, digital tools, and collaborative learning. *International Journal of Computer-Supported Collaborative Learning*, 14(4), 415–423.

Wise, A. F., & Schwarz, B. B. (2017). Visions of CSCL: Eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, 12 (4), 423-467.

Yang, Y. van Aalst, J., Chan, C.K.K. & Tian, W. (2016). Reflective assessment in knowledge building by students with low academic achievement. *International Journal of Computer-Supported Collaborative Learning*, 11 (3), 281-311.

Early Career Workshops



International Society of
the Learning Sciences



Integrated STEM Education: Empowering Students' Epistemic Agency through Ambitious Instruction

Jooeun Shim, University of Pennsylvania, jshim@gse.upenn.edu

Abstract: My research broadly focuses on improving integrated STEM education by fostering epistemic agency through an Ambitious Instruction (AI) approach. It encompasses developing learning tools based on geospatial technology to promote AI, advancing teacher professional development focusing on integrating data literacy in STEM, and creating AI curricula that encourage students to create digital artifacts. My future research will investigate design principles for empowering students as active agents in knowledge construction and application.

Introduction and background

My research focuses on investigating ways of improving integrated Science, Technology, Engineering, and Mathematics (STEM) education by supporting students and teachers in developing epistemic agency. Epistemic agency, as defined by Miller et al. (2018), is a student's ability to actively shape their knowledge-building practices, including their decisions about what to learn and how to learn it, as well as the application of this knowledge in a variety of contexts. A critical aspect of this approach is STEM integration, where knowledge and practices from diverse STEM disciplines are applied to understand and solve complex, real-world problems, a concept increasingly recognized as important in science education (Nadelson & Seifert, 2017). However, studies continue to reveal that school science instruction typically focuses on teaching facts rather than the practices and application of science (Chinn et al., 2023). To address this, my research employs ambitious instruction to engage students in the authentic practices of scientific subjects. Ambitious instruction is a pedagogical approach that immerses students in tasks that are authentic to the discipline and driving learning from their prior experiences. This approach not only encourages students to become active agents in knowledge construction but also helps transform their learning into action (Berland et al., 2016). My work, therefore, focuses on epistemic agency within STEM education in K-12 classrooms through three interconnected areas: designing learning tools using geospatial technology, providing comprehensive professional development (PD) supports for teachers, and developing curricula for action.

Designing interactive learning tools to foster ambitious instruction

My first area of research focuses on designing learning tools using geospatial technologies for ambitious instruction. I ask how emerging technologies can foster students' epistemic agency and support student engagement in real-world applications of scientific knowledge. To do so, I developed a smartphone app and mobile sensors to detect air quality in different locations within students' communities as part of an NSF-funded research project designed to enhance the teaching of bioinformatics as a STEM-integrated discipline. Using design-based implementation research (DBIR) method (Penuel, 2019), I also designed a place-based learning curriculum that worked alongside the devices. This curriculum was implemented by science teachers for four iterations, engaging students in investigating how air quality is related to asthma, how various factors in the exposome of their local geographic areas affect health, and how students can improve environmental conditions in their communities (Shim et al., 2021). This research contributes to science education by highlighting how learning tools can enhance epistemic agency, realizing authentic scientific practices through a curriculum designed for hands-on investigation into the places where students live and learn. In future research, I will explore how places create opportunities for students to not just view data as objective numbers but rather to use this data to reassess their beliefs related to the topic being investigated. I anticipate that these studies will provide new theoretical perspectives on learning with and about technologies that foreground culture and place.

Providing support and PD for teachers

My second research focus relates to teacher PD. The goal is to help teachers enact rigorous and adaptive learning opportunities for ambitious instruction. To investigate how in-service teachers learn and teach STEM, particularly in the context of data literacy integration, I employed constant comparison analysis. This involved using data such as classroom observation recordings, teacher and student interviews, pre- and post-surveys, and student artifacts. In this process, I examined various teacher competencies that are essential for the successful integration of data literacy into science classes. These competencies include confidence in using data analysis tools, a deep conceptual understanding of data literacy (Shim et al., 2021), the ability to activate various educational resources



(i.e., material, cultural, social, and symbolic resources) (Shim & Yoon, 2023), and the capacity to acquire adaptive expertise (Yoon et al., 2022). Building on these findings, my subsequent research has explored how teachers can create environments that foster students' epistemic agency in data literacy as comprehension, critique, and participation in online environments (Shim et al., 2022). In future research, I intend to focus on creating research-practice partnerships with local science teachers. Together, we will explore how best to support their efforts to foster students' epistemic agency in STEM contexts to enable students to become active agents of their own knowledge construction.

Developing curricula for students creating digital artifacts for action

My third area of research focuses on curriculum design for ambitious instruction that encourages students to learn through the creation of digital artifacts. This approach seeks to provide students with additional opportunities in formal learning classrooms by empowering them, particularly underrepresented students in STEM education, to transform learning into action. For example, I created and implemented a 12-week curriculum for middle school science classes where students used the App Inventor platform to construct their own mobile apps addressing and examining socioscientific issues in their local communities. The findings from this project suggest that engaging in socioscientific problem-solving empowers students to proactively improve their local communities by developing technologies for social good (Shim et al., 2019). In addition, I applied DBIR to analyze two iterations of the curriculum, and the results indicated that crafting digital artifacts sharpened students' reasoning capabilities and grounded their knowledge acquisition in activities that resonated with their personal and cultural backgrounds (Yoon et al., 2018). By integrating mobile app construction activities into science education, my work identified a powerful way to incorporate creating digital artifacts into science classes while also highlighting the need to carefully consider the associated benefits and challenges. The future direction of my research will focus on delineating curricular design principles that enhance students' epistemic agency and foster meaningful actions.

References

Ballard, H. L., Dixon, C. G. H. & Harris, E. M. (2017). Youth-focused citizen science: Examining the role of environmental science learning and agency for conservation. *Biological Conservation*, 208, 65-75.

Chinn, C. A., Yoon, S. A., Hussain-Abidi, H., Hunkar, K., Noushad, N. F., Cottone, A. M., & Richman, T. (2023). Designing learning environments to promote competent lay engagement with science. *European Journal of Education*, 58(3), 407-421.

Miller, E., Manz, E., Russ, R., Stroupe, D. and Berland, L. (2018), Addressing the epistemic elephant in the room: Epistemic agency and the next generation science standards. *Journal of Research in Science Teaching*, 55(7).1053-1075.

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *The Journal of Educational Research*, 110(3), 221-223.

Penuel, W. R. (2019). Infrastructuring as a practice of design-based research for supporting and studying equitable implementation and sustainability of innovations. *Journal of the Learning Sciences*, 28(4-5), 659-677.

Shim, J. & Yoon, S. A. (2023). Activating resources for incorporating culturally relevant teaching in STEM curricula. In P. Blikstein, J. V. Aalst, R. Kizito, & K. Brennan (Eds.), *Proceedings of the 17th International Conference of the Learning Sciences - ICLS 2023*. (pp. 858-861). Montreal, Canada.

Shim, J., Yoon, S. A., Cottone, A., & Miller, K. (2021). Two exploratory case studies of teachers' adaptive expertise in teaching bioinformatics in high school science classrooms. In E. de Vries, Y. Hod, & J. Ahn (Eds.), *Proceedings of the 15th International Conference of the Learning Sciences - ICLS 2021*. (pp. 1021-1022). Bochum, Germany.

Shim, J., Yoon, S., & Noushad, N. (2019). Using a resource activation lens to understand classroom enactments of computationally-based science curricula. In K. Lund, G. P. Niccolai, E. Lavoué, C. Hmelo-Silver, G. Gweon, & M. Baker (Eds.), *A Wide Lens: Combining embodied, enactive, extended, and embedded learning in collaborative settings, Proceedings of the 13th International Conference on Computer Supported Collaborative Learning - CSCL 2019, Volume 2* (pp. 937-938). Lyon, France.

Yoon, S. A., Shim, J., Miller, K., Cottone, A., Noushad N., Yoo, J., Gonzalez, M. V., Urbanowicz, R., & Himes, B. E. (2022). Professional development for STEM integration: Analyzing bioinformatics teaching through considerations of adaptive expertise and cognitive load. In *Teacher Learning in Changing Contexts* (pp. 69-90). Routledge.

Yoon, S. A., Shim, J., & Noushad, N. F. (2019). Trade-offs in using mobile tools to promote scientific action with socioscientific issues. *TechTrends*, 63(5), 602-610.



A Two-Pronged Approach for Improving Mathematics Education at Scale: Researching Teacher Learning and Organizational Change

Phi Nguyen, University of Illinois Chicago, pknguyen@uic.edu

Abstract: Improving mathematics education at scale requires changing teachers' practice *and* organizing teachers' work settings in ways that support their ongoing learning. Addressing both these problems of teacher learning and organizational change, my research investigates (1) coherence in mathematics teacher education programs and (2) education policy as designs for supporting learning. My research informs design principles for teacher education programs, as well as researchers and educational leaders engaged in policymaking for mathematics.

Introduction

The challenge of enacting equitable and ambitious mathematics education across a large number of classrooms has been well-documented. Part of this challenge is that supporting teachers to improve their instruction also requires changing the institutional settings in which teachers work. As such, learning scientists have increasingly turned their attention to developing educational systems and their capacity to support teachers' ongoing learning (e.g., Cobb et al., 2020). Improving mathematics education at scale, then, is a problem of teacher learning *and* organizational change. My research investigates both these problems through two strands: (1) coherence in mathematics teacher education programs; and (2) education policy as designs for supporting learning. In examining learning across multiple scales and contexts, my research employs mixed-methods approaches drawing from qualitative research, discourse analysis, social network analysis, and participatory diagramming.

Coherence in mathematics teacher education programs

Teacher education is often fragmented, with different settings promoting different ideas. To combat this, teacher educators have argued for program *coherence*, as research has found that more coherent programs have a greater impact on teachers' learning (e.g., Boyd et al., 2009). To understand preservice teachers' (PSTs) perceptions of coherence, in one study (Nguyen & Munter, 2023) I engaged 13 secondary mathematics PSTs in participatory diagramming interviews (Bravington & King, 2019) where they were invited to create visual diagrams that represented the connections and disconnections they perceived among the various ideas they engaged with in their teacher education program. Analysis involved qualitative coding of interviews, and then transforming that coding into network data to create and visually analyze network maps. This helped to uncover the structure underlying PSTs perceptions of incoherence, including that (1) equity and other aspects of mathematics teaching were not conceptually integrated, and (2) opportunities to learn about inquiry-based instruction in mathematics methods courses were undermined by limited opportunities to experience it in field, and by experiencing direct instruction in mathematics and special education courses. By identifying where, how, and with respect to what PSTs perceive (in)coherence, my research points to specific sources of tension and contradiction that teacher educators can address in their design of learning experiences and programmatic structures. Specifically, this research highlights that the design of teacher education programs should attend to both *conceptual* coherence (unifying ideas and a shared instructional vision across programmatic content) as well as *structural* coherence (organizing and sequentially aligning program components around shared ideas; see Feiman-Nemser, 1990).

Education policy as designs for supporting learning

Because the broader institutional contexts in which teachers work shape their agency and practice (e.g., Nguyen et al., 2022), in the second strand of my research, I focus on how education policy might be designed to support teachers in learning to improve their practice. Theoretically, I am guided by Cobb and Jackson's (2012) learning design perspective which views education *policy as designs for supporting learning*. By highlighting the learning demands of changing practice, and the supports for facilitating that learning, this perspective enables learning scientists to anticipate the limitations of designed policy and explain why enacted policy unfolded the ways it did. For example, in an interview study with leaders in 50 districts across one U.S. state (Munter, Nguyen & Kinder, 2023), my colleagues and I found that, for the challenge of improving standardized test scores, leaders were more likely to adopt a "management" frame where policy responses focused on changing district programs (e.g., adopting new curriculum), rather than a "learning" frame focused on supporting and developing staff (e.g., professional development). From the learning design perspective, our findings call attention to the gap between



“management” policies and the learning demands of (and supports necessary for) changing teachers’ practice (e.g., teachers also need to develop mathematical knowledge for teaching, as well as new instructional practices).

My doctoral research builds upon this work by taking a disciplinary lens in considering how school subjects operate as unique contexts for policymaking (Grossman et al., 2004). Compared to subject-neutral approaches to policy research, I focus on the ways educational leaders draw upon systems of meaning about the subject in their sensemaking and enactment of policy (Nguyen, forthcoming). For example, in a case study of two school districts, I analyzed the interaction between leaders’ sensemaking between mathematics and equity, and their policy solutions for addressing inequity. Through a discourse analysis of policy artifacts, interviews with educational leaders, and observations of policymaking, I found that leader’s meaning-making about the core and heavily-tested nature of mathematics constrained sensemaking about equity in mathematics to access and achievement concerns, which translated to technical policy solutions for addressing achievement (gaps). However, normative policy solutions attending to students’ identities were rendered relevant to social studies but peripheral to mathematics, because leaders made sense of these policies as incompatible with mathematics’ *sequentiality* (where mastery of prior learning is necessary for future learning) and *definition* (where there is agreement over what counts as mathematics content, because mathematics is objective and “black and white”), especially as compared to the cultural relevance of social studies. For the learning sciences, my findings suggest that meanings about the subject pose learning demands that policymakers should address in their policy designs.

Future work and contributions to the learning sciences

My two research strands converge, and inform one another. For example, in both strands is the *boundary* (Lamont & Molnár, 2002) separating and distinguishing equity from mathematics teaching, where participants—whether they were district leaders or preservice teachers—have not integrated ideas related to equity into their (emerging) visions for (improving) mathematics instruction. In my future work, I plan to examine the subject-specific meanings that contribute to maintaining or erasing this boundary, which will inform the development of a model for teacher and leader learning that incorporates aspects of both equitable and ambitious mathematics instruction. Specifically, I am expanding my work on program coherence by studying how teacher educators, across a variety of content areas, design their coursework around issues of equity, specifically attending to how meanings about the subject shape their curricular design. This would broaden the field’s understanding of program coherence for equity and content area instruction, and inform design principles that teacher education programs might use in their coherence efforts. Second, I plan on partnering with educational leaders that are working to support teachers in equitable and ambitious mathematics education. Here, I hope to engage in co-design of policies that anticipate and meet the learning demands of the school subject, which would include data collection cycles to examine how enacted policies unfold and might be redesigned to better support teacher learning.

References

Boyd, D. J., Grossman, P. L., Lankford, H., Loeb, S., & Wyckoff, J. (2009). Teacher preparation and student achievement. *Educational Evaluation and Policy Analysis*, 31(4), 416–440.

Bravington, A., & King, N. (2019). Putting graphic elicitation into practice: Tools and typologies for the use of participant-led diagrams in qualitative research interviews. *Qualitative Research*, 19(5), 506–523.

Cobb, P., & Jackson, K. (2012). Analyzing educational policies: A learning design perspective. *Journal of the Learning Sciences*, 21(4), 487–521.

Cobb, P., Jackson, K., Henrick, E., & Smith, T. M. (2020). *Systems for instructional improvement: Creating coherence from the classroom to the district office*. Harvard Education Press.

Feiman-Nemser, S. (1990). Teacher preparation: Structural and conceptual analysis. In W. R. Houston, M. Haberman, & J. Sikula (Eds.), *Handbook of research on teacher education* (pp. 212–233). Macmillan.

Grossman, P., Stodolsky, S. S., & Knapp, M. S. (2004). Making subject matter part of the equation: The intersection of policy and content. *University of Washington*.

Lamont, M., & Molnár, V. (2002). The study of boundaries in the social sciences. *Annual Review of Sociology*, 28(1), 167–195.

Munter, C., Nguyen, P., & Kinder, C. (2023). Framing school mathematics challenges inside and outside metropolitan areas. *Teachers College Record*, 125(2), 35–65.

Nguyen, P. (forthcoming). What is (school) mathematics?: Subject-matter as context for educational policymaking. *Educational Studies in Mathematics*.

Nguyen, P., & Munter, C. (2023). Secondary mathematics preservice teachers’ perceptions of program (in)coherence. *Journal of Mathematics Teacher Education*.

Nguyen, P., Webel, C., Yeo, S., & Zhao, W. (2022). Elementary teachers’ agency: The role of perceived professional space and autonomy. *Journal of Curriculum Studies*, 54(5), 665–686.



Deliberate, Guided Failure

Tanmay Sinha, National Institute of Education, Nanyang Technological University, tanmay.sinha@nie.edu.sg

Abstract: *Deliberate, guided failure* refers to an instructional design that problematizes student understanding by offering them to work with suboptimal problem-solving representations (designed to lead to failures) before formal instruction. I briefly highlight the rationale and empirical evidence supporting this design in the following paper, and outline three strands of my ongoing and future research on *deliberate, guided failure* within authentic learning contexts.

Introduction

Can learning be enriched by embracing failure? Many educational systems shy away from failure-driven learning, emphasizing instruction-first methods. Yet, learning from failure cultivates resilience and adaptability (Sinha & Kapur, 2021a; de Jong et al., 2023). My research, which I will henceforth call *deliberate, guided failure*, explores intentionally introducing failure moments into education. Situated within the context of arguing and working with data, now commonplace across several study domains in secondary / higher education, I ask whether students can benefit from directly exploring suboptimal problem-solving representations before formal instruction. Suboptimal representations, designed to lead to incorrect or subpar solutions, are integral to this approach of guiding students to experience failure, contrasting naturally (and sometimes infrequently!) occurring failures during the learning design of *productive failure* (Kapur, 2016). For instance, in supervised machine learning, noise-inducing features or poorly chosen algorithm parameters deliberately create suboptimal outcomes. Similarly, social network analysis can involve suboptimal measures that disregard network quality to evaluate the importance of a node. Across most domains of data-driven inquiry, there are typically multiple such suboptimal ways of approaching a problem, each having their tradeoffs. How can students be exposed to these tradeoffs to enhance their likelihood of transferring learned concepts to new contexts? Traditionally, instruction-first routines emphasize *why right is right* without addressing *why wrong is wrong*. My approach uses problem-solving before formal instruction (Loibl et al., 2017), where students directly engage with suboptimal representations within tasks aligned with domain practices. This occurs before lectures, inducing mispredictions and negatively valenced emotions such as shame, confusion and anger (Sinha, 2022). However, this temporarily induced discomfort fuels deeper exploration by making students attend to unexplored parts of the problem-space, raises their knowledge gap awareness and curiosity to know the canonical answer, in turn fostering readiness to learn and promoting conceptual understanding and transfer. Empirical evidence (Sinha et al., 2021; Sinha & Kapur, 2021b; Thorgeirsson et al., 2022) supports the effectiveness of such *deliberate, guided failure* over unscaffolded problem-solving during *productive failure* and success-driven scaffolding prior to instruction. Educators interested in leveraging the learning benefits of suboptimal problem-solving before instruction must establish a classroom climate that appreciates failure, empathizes with and aids in managing emotions.

Methods

I foreground methods such as experimental design, inferential statistics, multimodal learning analytics, and quantitative coding of qualitative data. For example, my experimental studies on *deliberate, guided failure* (Sinha et al., 2021; Sinha & Kapur, 2021b), conducted for individuals, used validated questionnaires and facial expression analyses to gather process data on salient learning mechanisms and student emotions. I further performed a meta-analytic expansion of research on the differential efficacy of instruction-first or problem-solving first approaches for learning (Sinha & Kapur, 2021a), particularly focusing on when and under what contextual conditions does each approach show a greater (dis)advantage. To overcome limitations of null hypothesis significance testing, I also typically use Bayesian analyses to provide evidence complementary to frequentist statistics. My ongoing work is beginning to collect more qualitative data on students' learning experiences and subjective perceptions on relevant constructs (e.g., emotions, their intra/inter-personal triggers and regulation strategies) to triangulate evidence for how students behave multimodally during *deliberate, guided failure*.

Plans for moving forward

Improving the desirability of difficulties during *deliberate, guided failure*

Students often shy away from challenging and failure-prone learning activities, influenced by their reluctance. Despite short-term performance dips, these activities, such as engaging in *deliberate, guided failure* prior to

formal instruction, can potentially enhance long-term learning. Limited willingness to embrace the inherent challenges of such activities may result from institutional factors, parental influence, and existing pedagogical practices. Yet, no interventions have been proposed to improve these beliefs, emphasizing the need to understand how to make failures and challenges desirable for students to enhance their learning of how to learn. Drawing on motivational tactics and refutational teaching (Zepeda et al., 2020), I plan to design prompts to investigate how deliberate engagement with failures can be enhanced and how students' desirability towards embracing challenges can be improved. These prompts will confront students with typically (surprising!) counter-evidence on the effectiveness of *deliberate, guided failure* and provoke opportunistic reflection to increase its perceived relevance.

Understanding the causal role of emotions in *deliberate, guided failure*

Traditional classroom research and practice aims to regulate student emotion by relying on hedonic motives of increasing pleasure and decreasing pain, implicating that students should not dwell on the negative and instead always try to feel better by putting a positive spin on such emotions. However, when designing for learning using *deliberate, guided failure*, it is important that students distinguish the valence of an emotion from its usefulness in attaining task goals (e.g., shame / happiness is not monotonically bad / good for learning). Grounded in instrumental theoretical accounts of emotion regulation (Tamir, 2016), which emphasize what we feel depends on both pleasure and utility, I plan to carry out studies that will manipulate whether students increase (maintain) or decrease their experience of positively and negatively valenced emotions, and how that impacts learning.

Technology to improve the socio-emotional context of *deliberate, guided failure*

Working on data-rich problems situated within *deliberate, guided failure* requires understanding of disciplinary formalisms, persisting through frustration and regulating emotions. Lack of socio-emotional support, which makes learning engaging and meaningful, can further aggravate task demands. Drawing on advances in open-domain dialog understanding, multimodal emotion measurement, nonverbal behavior generation and human-like agent design, I would like to examine the potential for developing virtually embodied pedagogical agents (Johnson & Lester, 2016) to provide dynamic cognitive and affective scaffolds during failure-driven learning.

References

de Jong, T., Lazonder, A. W., Chinn, C. A., Fischer, F., Gobert, J., Hmelo-Silver, C. E., ... & Zacharia, Z. C. (2023). Let's talk evidence—The case for combining inquiry-based and direct instruction. *Educational Research Review*, 100536.

Johnson, W. L., & Lester, J. C. (2016). Face-to-face interaction with pedagogical agents, twenty years later. *International Journal of Artificial intelligence in education*, 26, 25–36.

Kapur, M. (2016). Examining productive failure, productive success, unproductive failure, and unproductive success in learning. *Educational Psychologist*, 51(2), 289–299.

Loibl, K., Roll, I., & Rummel, N. (2017). Towards a theory of when and how problem solving followed by instruction supports learning. *Educational Psychology Review*, 29, 693–715.

Sinha, T., Kapur, M., West, R., Catasta, M., Hauswirth, M., & Trninic, D. (2021). Differential benefits of explicit failure-driven and success-driven scaffolding in problem-solving prior to instruction. *Journal of Educational Psychology*, 113(3), 530–555.

Sinha, T., & Kapur, M. (2021a). When problem solving followed by instruction works: Evidence for productive failure. *Review of Educational Research*, 91(5), 761–798.

Sinha, T., & Kapur, M. (2021b). Robust effects of the efficacy of explicit failure-driven scaffolding in problem-solving prior to instruction: A replication and extension. *Learning and Instruction*, 75, 101488.

Sinha, T. (2022). Enriching problem-solving followed by instruction with explanatory accounts of emotions. *Journal of the Learning Sciences*, 31(2), 151–198.

Tamir, M. (2016). Why do people regulate their emotions? A taxonomy of motives in emotion regulation. *Personality and Social Psychology Review*, 20(3), 199–222.

Thorgeirsson, S., Sinha, T., Friedrich, F., & Su, Z. (2022). Does deliberately failing improve learning in introductory computer science?. In *European Conference on Technology Enhanced Learning* (pp. 608–614). Cham: Springer International Publishing.

Zepeda, C. D., Martin, R. S., & Butler, A. C. (2020). Motivational strategies to engage learners in desirable difficulties. *Journal of Applied Research in Memory and Cognition*, 9(4), 468–474.

Acknowledgments

T.S. is supported by the National Institute of Education, Singapore under a Start-up Grant (NIE-SUG 5-23 TS).



Taking a Relational Approach to Study Learning: Science Education in and with the More Than Human World

Rishi Krishnamoorthy, Pennsylvania State University, rkrish@psu.edu

Abstract: My research agenda broadly examines how sociopolitical powered dynamics contribute to the reproduction of inequities in science learning environments, and within South Asian communities in school settings. Drawing on interaction analysis methods and through a relational ontology, my scholarship illustrates how everyday teaching and learning interactions are deeply entangled with and shaped by ideologies from larger social worlds, becoming critical sites for the reproduction and disruption of colonial logics. Here, I describe research emergent through two strands of scholarship: 1) Examining the reproduction of Hindu supremacy within Indian communities through school science education and 2) Co-designing justice-oriented biology curricula that explicitly entangles human biology with the environment.

Theories that inform my work

My research contributes to ongoing efforts in the Learning Sciences that disrupt the settled sociocultural, historical, and political powered dynamics that shape everyday teaching and learning interactions. Broadly, I study how ideologies from larger social worlds – informed through post and settler colonialism, racism, homophobia and more – shape how knowledge is created in science learning environments. Learning from Indigenous ways of knowing (Marin & Bang, 2018), my own community's ways of knowing and being, and feminist materialisms (Barad, 2007), my current projects are grounded in a relational ontology that bring relations between humans and the More Than Human (MTH; Marin & Bang, 2018) world to the fore. Building on interaction analysis methods (Jordan & Henderson, 1995), my research methodology shifts from a focus on humans to human-MTH relations as the unit of analysis (Krishnamoorthy, 2023). I examine how our (present, past and future) relations with the MTH world - land, water, classroom materials (e.g., desks, chairs, poster papers) and more - are shaped by macro-scale ideologies (e.g., nationalism, homophobia). I take up this approach to research through two strands of scholarship: 1) Examining how Hindu supremacy contributes to creating inequitable learning environments within South Asian contexts and 2) Building justice-oriented (Morales-Doyle, 2017) science curricula framed through the Rightful Presence (Calabrese Barton & Tan, 2019) framework to facilitate science learning that necessitates disrupting inequities in youths' relations in and with their learning environments. Across both strands, I aim to be part of scholarship in the Learning Sciences that desettles colonial understandings of learning while recognizing the expansive ways that youth make-meaning in science learning environments.

Past and current research

My dissertation research examined the reproduction of inequity within South Asian communities by illuminating how ideologies emergent through precolonial ways of knowing and being, such as caste, Hindu supremacy, and sexuality, contributed to everyday teaching and learning interactions. I worked with teachers in a rural school in South India and traced the systems of oppression that informed whose knowledge was privileged in both science classrooms and informal interactions. Grounded in a relational ontology, I developed intra-action analysis (Krishnamoorthy, 2023) that shifted away from a focus on human action and instead analyzed human-MTH relations. This shift in analytic methods illustrated how classroom science phenomena and science teaching interactions were not neutral. Instead, they were deeply rooted in Hindu nationalism, settler colonialism, Islamophobia, and homophobia. Seemingly neutral lessons on the immune system reproduced settler colonialism through anti-Kashmiri and Hindu supremacist ideologies (Krishnamoorthy & Ma, 2021). Analysis of teachers' interactions in the lunchroom revealed the caste-privileged ways of knowing and being that structured informal interactions. For example, contact between a used spoon and a bowl of yogurt was framed as 'unclean' and therefore 'not allowed' in the lunch room. This seemingly neutral interaction – the request for teachers' used spoons to not touch the yogurt container – was asserted as an 'Indigenous' (vs caste-privileged) knowledge practice thereby making invisible upper-caste Hindu supremacy in the school. My work further detailed how queer identities were shaped into being invisible within school spaces (Krishnamoorthy, 2022). With India witnessing a rise in violence and discrimination against Muslim and queer communities, this research illustrated the need for teachers to pay attention to everyday seemingly neutral interactions as critical sites for resisting the reproduction of inequity in and through science education. One contribution of this work to current decolonization efforts in

the Learning Sciences includes nuancing how human-MTH relations (i.e., human relations in and with our environments) are not neutral but shaped by socio-cultural-political histories around caste, religion, and sexuality.

My current research builds on this scholarship through the design of curricula that explicitly recognizes human physiology as entangled with and shaped by the environment. I am currently involved in ‘Bio4Community’, a project in collaboration Dr. Ravit Duncan, Dr. Edna Tan, and Dr. Frida Reichman. The project draws on community-engaged and critical participatory design research methods (Bang & Vossoughi, 2016), working with a team of middle school youth, local teachers, and university researchers. The end-product is a technology-integrated 7th grade biology unit that engages youth in learning about a community-identified health issue, ‘stress’. The unit is designed through a relational ontology where understandings of human physiology (i.e., cortisol secretion from adrenal glands) are entangled with racism, class-based discrimination, and homophobia. Youth learn about the biology of short- and long-term stress by linking local stressors in their community to broader sociopolitical policies and those enforced in their school. The culminating design outcome of the unit includes youth developing proposals for change, presented to the school administrators. Through this project, my research focus has included: 1) An examination of youths’ resistance to Eurocentric science disciplinary practices through their commitment to an ethic of care and 2) A study of the multiple expansive and political ways of knowing that youth drew on, when modeling long-term stress (Krishnamoorthy et al., 2023).

Future research

I am beginning work on the ‘Just Genetics’ project in collaboration with Dr. Ravit Duncan. We are collaborating with biology teachers to design a high school genetics unit grounded in a relational ontology where the MTH world is understood as a political space shaped through (often) oppressive policies, and structures. Across the lessons, human genetics emerges as entangled with the environment – a non-neutral MTH world. The unit will be piloted in New Jersey and then revised in collaboration with South Asian teachers and youth in Ontario, Canada. Building on my ongoing scholarship, the unit will entangle the high school genetics curriculum with sociopolitical histories around caste and sexuality in the South Asian diaspora. I aim to contribute to a deeper understanding of the intersectional powered dynamics shaping South Asian youths’ learning in and with their worlds.

References

Bang, M., & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making. *Cognition and Instruction*, 34(3), 173–193. <https://doi.org/10.1080/07370008.2016.1181879>

Barad, K. M. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Duke University Press.

Calabrese Barton, A., & Tan, E. (2019). Designing for rightful presence in STEM: The role of making present practices. *Journal of the Learning Sciences*, 28(4–5), 616–658.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, 4(1), 39–103. https://doi.org/10.1207/s15327809jls0401_2

Krishnamoorthy, R. (2022). Caste and queerness in Hindu India: Examining how human-more than human relations shape learning spaces. In Chinn, C., Tan, E., Chan, C., & Kali, Y. (Eds.), *Proceedings of the 16th International Conference of the Learning Sciences - ICLS 2022* (pp. 1569-1572).

Krishnamoorthy, R. (2023). Intra-action analysis of emergent science phenomena: Examining meaning-making with the more than human in science classrooms. *Cultural Studies of Science Education*. <https://doi.org/10.1007/s11422-023-10148-5>

Krishnamoorthy, R. & M, J. Y. (2021). The immune system and Hindu nationalism: Nation making in a grade 8 biology lesson. In de Vries, E., Hod, Y., & Ahn, J. (Eds.), *Proceedings of the 15th International Conference of the Learning Sciences - ICLS 2021*. (pp. 1059-1060). International Society of the Learning Sciences.

Krishnamoorthy, R., Tan, E., Duncan, R. G., Dabholkar, S., & Smithen, B. (2023). Probing beyond the biology: Centering a relational ontology in middle-school science modeling towards rightful presence. In Blikstein, P., Van Aalst, J., Kizito, R., & Brennan, K. (Eds.), *Proceedings of the 17th International Conference of the Learning Sciences - ICLS 2023* (pp. 266-273). International Society of the Learning Sciences.

Marin, A., & Bang, M. (2018). “Look it, this is how you know:” Family forest walks as a context for knowledge-building about the natural world. *Cognition and Instruction*, 36(2), 89-118. <https://doi.org/10.1080/07370008.2018.1429443>

Morales-Doyle, D. (2017). Justice-centered science pedagogy: A catalyst for academic achievement and social transformation. *Science Education*, 101(6), 1034–1060. <https://doi.org/10.1002/sce.21305>



Using Multimodal Collaboration Analytics to Support Collaborative Problem Solving

Rogers Kaliisa, Department of Education, University of Oslo, Oslo, Norway, rogers.kaliisa@iped.uio.no

Abstract: In this submission to the ISLS Early Career Workshop, I describe my current research focus centered on the use of multimodal collaboration analytics to support collaborative problem solving in professional settings. Methodologically, my research is guided by a design-based research approach, where I employ qualitative and quantitative methodologies (using verbal and non-verbal data) to study and support students' learning from a sociocultural approach. My future research directions include leveraging a hybrid human-AI approach to ensure fair, pedagogically relevant and personalized teaching and learning experiences to both teachers and students.

Introduction: Research focus

In the multidisciplinary field of Learning Sciences, my research stands at the forefront of integrating educational technologies (in particular, learning analytics) to understand and support learning and teaching. My research focus is motivated by the continuous changes in higher education and the increased responsibilities that such changes bring to teachers and students albeit limited support structures. One potential strategy is to use proactive, automated, and timely approaches to information gathering to inform and empower teachers with prompt insights into students' participation, engagement, and performance. With higher education becoming increasingly digitized, institutions have access to a higher volume of student (learning and demographic) data, creating opportunities for collecting and analyzing this data, and sharing it with students and teachers to offer timely and data-informed teaching and student support. This context is the catalyst of my research focus, which explores how data-supported approaches, particularly learning analytics (LA), a field that strives to employ algorithmic techniques of data mining and analysis, can be leveraged to support students and teachers in blended and technology-enhanced learning environments.

In my PhD project, guided by a design-based research (DBR) approach and concepts from the socio-cultural perspective (Säljö, 2009) and human-computer interaction (HCI), I developed a teacher-facing LA dashboard, the Canvas Discussion Analytics Dashboard (CADA) (Kaliisa & Dolonen, 2022) to support teachers' in gaining insights into their students' participation and discourse patterns during asynchronous online discussions. CADA, a pioneering Canvas plugin at the University of Oslo, provides an overview of both structural and content-level analytics, which helps teachers in gaining insights into students' learning processes during asynchronous online discussions.

Building from my PhD project, my current postdoctoral research project is focused on using multimodal collaboration analytics (MMCA) to support professional teams during collaborative problem solving. Due to the digitization of work and education, collaboration and teamwork require the integration of knowledge across multiple systems distributed across people and machines (Wise et al., 2021). Recent work (e.g., Cukurova et al., 2018) found that developing clear measures of individual or team behavior in collaborative learning settings is difficult and time consuming, due to the complex simultaneous interplay of multiple behaviors during collaborative activities, which are difficult to capture and process in a fast and reliable manner. However, advancing technology has made it possible to develop approaches to analyze and support students' collaborative learning in digital and collocated settings by means of MMCA. The nature of MMCA range from low-level logs, such as clickstreams which are easily captured at a scale without observers influencing the activity, verbal and non-verbal indicators ranging from tangible interaction (e.g., gesture, posture, and head or hand orientation), speech-based cues (e.g., non-lexical speech features, speech-activity features, and speaker-based features), to gaze and eye interaction (Blikstein & Worsley, 2016), all with potential to facilitate feedback and assessment of CPS processes.

In my current project which is part of a large project (TeamLearn) aiming to study how collaborative problem solving (CPS) can be guided by providing automated feedback to student teams about their teamwork during and after CPS in online and co-located environments, the focus is on providing automated and timely analytics to collaborating groups overtime to support their reflection and group awareness. Preliminary findings have shown that students' CPS strategies and interactions from students' interactions can provide insight into their epistemic and regulatory process, which if analyzed and shared with students, might support cognitive and metacognitive regulation processes (Kaliisa et al., 2023).

Theoretical approach

One of the criticisms against the field of learning analytics is the lack of theoretical support from the learning sciences, which makes it difficult for users to make sense of the analytics presented in learning analytics systems and to inform their everyday practices. Researchers have argued that the analytics element has received more attention, particularly among researchers who take an empiricist data-driven approach and consider data to be the starting point and endpoint without relying on theoretical preconceptions. To deal with this limitation, the theoretical underpinning of my research is rooted in the sociocultural approach which emphasizes the role of social context and cultural tools in shaping cognitive development (Säljö, 2009). In alignment with this approach, my work explores how digital tools and collaborative environments act as mediators of learning, facilitating the construction of knowledge and the development of higher-order thinking skills.

Methodological approach

My research methodologies are diverse, encompassing both qualitative and quantitative approaches. This dual methodological approach allows me to capture the richness and complexity of learning processes in a nuanced manner. Techniques such as social network analysis and epistemic network analysis enable me to examine the patterns and quality of interactions within learning communities. These analyses are crucial in understanding collaborative learning dynamics and social constructs' role in knowledge acquisition. My overarching research approach is design-based research (DBR) which attempts to overcome the atheoretical nature of existing (data-driven) LA studies, since DBR envisions a more rigorous connection with learning theory that results in theoretical and practical contributions (Van den Akker et al., 2006). In this sense, I consider DBR a good fit between the learning sciences and learning analytics, both of which aim to provide solutions to practical educational problems. Thus, I use DBR to support the design of tools through interactive and iterative design cycles with stakeholders (e.g., teachers and students), and to increase the understanding of how learning theories (e.g., the sociocultural perspective) can guide the development of LA tools and be improved upon based on the evidence generated during the design process.

Future research agenda

I conducted a bibliometric analysis of CSCL studies (*accepted as a short paper, CSCL 2024*) which showed that the potential of CSCL is huge due to its richness in methods, actors, technologies, and epistemological perspectives. At the same time, New emerging ideas and concepts, such as learning analytics, augmented reality, virtual reality, and generative artificial intelligence (AI), can expand the scope of where collaboration occurs and how it is studied and supported. As I look to the future, my research agenda is set to harness further the potential of new technological innovations in fostering inclusive learning and teaching. A key focus will be leveraging AI to support learning for underrepresented groups to create equitable learning opportunities.

References

Blikstein, P., & Worsley, M. (2016). Multimodal learning analytics and education data mining: Using computational technologies to measure complex learning tasks. *Journal of Learning Analytics*, 3(2), 220-23.

Cukurova, M., Luckin, R., Millán, E., & Mavrikis, M. (2018). The NISPI framework: Analysing collaborative problem-solving from students' physical interactions. *Computers & Education*, 116, 93-109.

Kaliisa, R., & Dolonen, J. A. (2023). CADA: a teacher-facing learning analytics dashboard to foster teachers' awareness of students' participation and discourse patterns in online discussions. *Technology, Knowledge and Learning*, 28(3), 937-958.

Kaliisa, R., Dane, J. O., Sanchez, D., Pratt, J., Damsa, C., & Scianna, J. (2023, October). Understanding Group Dynamics During Synchronous Collaborative Problem-Solving Activities: An Epistemic Network Approach. In the International Conference on Quantitative Ethnography (pp. 81-95). Cham: Springer Nature Switzerland.

Säljö, R. (2009). Learning, theories of learning, and units of analysis in research. *Educational Psychologist*, 44(3), 202–208. <https://doi.org/10.1080/00461520903029030>

Van den Akker, J., Gravemeijer, K., & McKenney, S. (2006). Introducing educational design research. In J. Van den Akker, K. Gravemeijer, & S. McKenney (Eds.), *Educational design research* (pp. 15–19). Routledge.

Wise, A. F., Knight, S., & Shum, S. B. (2021). Collaborative learning analytics. *International handbook of computer-supported collaborative learning*, 425-443.

Determining the Effectiveness of Authentic Learning

Valentina Nachtigall, Ruhr University Bochum, valentina.nachtigall@rub.de

Abstract: Authentic learning is a widely and diversely used concept in the field of the learning sciences. To date, studies that follow a clear definition and operationalization of authenticity and systematically examine the effects of authentic learning settings are lacking. To address this gap, my research focuses on the theoretical conceptualization and empirical investigation of the conditions and effects of authentic learning.

Theoretical framework and prior studies: *Effects of authentic learning*

During my doctoral studies, I examined the role of authentic learning activities in the development of interest and knowledge acquisition in secondary school students who attend an out-of-school lab for social sciences and humanities. Out-of-school labs are considered being authentic learning settings in terms of “disciplinary authenticity” (Shaffer & Resnick, 1999). According to this kind of authentic learning, students should learn by doing, for instance, by solving problems or addressing questions in the same way that professionals in a particular discipline do. By engaging students in such activities that authentically mimic the core features and processes of scientific ways of thinking and working, out-of-school labs are thought to foster students’ interest in and knowledge about scientific topics and practices (e.g., Stamer et al., 2021). Also, according to situated learning theory (e.g. Brown et al., 1986), authentically contextualized learning settings are assumed to promote students’ motivation to engage with the learning content and their understanding of the content. Building on the literature-based model of authenticity in teaching and learning contexts (Betz et al., 2016), it can be hypothesized that these effects are mediated by students’ perceived authenticity of the learning setting. Thus, only if students perceive the learning setting as authentic, it will affect their motivational and cognitive learning outcomes. Against this background, I investigated the effect of the intended authenticity of a learning activity on students’ perceived authenticity. In addition, I examined how these perceptions relate to students’ interest in and knowledge about scientific ways of thinking and working within the social sciences in two quasi-experimental studies. The two studies demonstrated no effect of the intended authenticity of the learning activity on students’ perceived authenticity. Moreover, students’ perceived authenticity correlated with their situational interest in the learning topic but not with their knowledge acquisition. I found similar differential effects of authentic learning settings that aimed for various intentions of authenticity (i.e., enabling personally meaningful learning experiences, reflecting daily life experiences, emulating the work of professionals, and/or connecting the learners to a wider community of practice) in a literature review of 50 studies (Nachtigall et al., 2022a). Specifically, the findings suggest that while certain features of authentic learning settings (e.g., authentic learning materials) are likely to evoke positive motivational effects, the same features may harm cognitive learning outcomes.

Research methods and current work: *Conditions for authentic learning*

Given the findings of my doctoral studies and the findings of my literature review, I have begun to theoretically and empirically determine the conditions for authentic learning in different contexts. In a theoretical way, I have started (in collaboration with David Williamson Shaffer and Nikol Rummel) to develop a model of authentic learning which assumes that authentic learning settings that include no or minimal guidance are likely to (only) evoke positive motivational and emotional reactions in learners, whereas authentic learning settings that include certain forms of guidance are likely to also promote cognitive learning outcomes without preventing the positive motivational effects. These two avenues are also reflected in my empirical work in which I focus on investigating both certain conditions that may affect learners’ perceived authenticity of a learning setting (and their motivational outcomes) as well as certain forms of guidance that may enhance the effectiveness of authentic learning for cognitive outcomes. I do this in three projects: (1) In my project funded by the German Research Foundation (DFG), I investigate students’ conceptions of scientists and their work as a condition that very likely influences how students perceive the disciplinary authenticity of learning settings that try to emulate scientific ways of thinking and working. For this purpose, I conduct semi-structured interviews and analyze the results using Epistemic Network Analysis (ENA: Shaffer et al., 2016). (2) In a further project, in which I collaborate with mathematics-education researchers, we investigate in quasi-experimental studies how video models with a varying degree of disciplinary authenticity (i.e., scientists vs. peers) affect students’ perceived authenticity of the learning environment. We additionally examine whether the observation of video models constitutes – in comparison to independent and often cognitively overstraining experimentation – an effective form of guidance to promote students’ knowledge acquisition. (3) A further project, in which I collaborate with history-education

researchers, focuses on examining, again in quasi-experimental studies, the effectiveness of different strategy trainings – as certain forms of guidance – for students' cognitive engagement with supposedly authentic learning materials, namely immersive and emotionalizing history-related 360° videos that pretend to enable authentic time journeys to the past (see Nachtigall et al., 2022b). The strategy trainings aim for disciplinary authenticity in the sense that they try to foster skills in students that historians need to deal with historical sources.

Outlook and future plans: *Theory of authentic learning*

Although my recent work has already begun to investigate conditions for authentic learning, it ran in parallel with my conceptual work on authentic learning. Hence, in my future work, I plan to systematically test the theoretical model I have been developing, thus contributing to an evidence-based model of the conditions, mechanisms, and effects of authentic learning. I firstly aim to investigate the features of a learning setting that are central to learners' perceived authenticity. As intended authenticity of the learning setting does not equal the authenticity perceived by the learner (e.g., Barab et al., 2000), it is necessary to examine what features of the learning setting learners perceive as authentic. Authenticity can be implemented in various ways (e.g., Shaffer & Resnick, 1999) and as these different ways could influence each other (e.g., Gulikers et al., 2005), they need to be varied systematically and tested for their impact on learners' perceptions. Afterwards, I plan to test the effects of these features on learners' motivational and cognitive learning outcomes. Based on findings of studies from different research areas related to authentic learning (e.g., immersive learning) and the findings of my literature review on authentic learning, differential effects of authenticity are likely, namely positive effects on motivational outcomes but no effects on cognitive outcomes. Building on instructional theories and learning frameworks, such as cognitive apprenticeship (Collins et al., 1991) which emphasize the importance of guidance for knowledge acquisition, I aim to examine whether the provision of guidance can increase the cognitive effects of authentic learning settings. Additionally, following research on authentic assessments calling for a stronger alignment between learning activity and assessment of the outcomes of this activity (e.g., Gulikers et al., 2004), I am interested in investigating the role that the authenticity of the assessment plays for capturing the effects of the authentic learning setting on learners' knowledge acquisition. Thus, I envision contributing to the so far lacking knowledge about the conditions, mechanisms, and effects of authentic learning through systematic empirical investigations and the development of an evidence-based theoretical model.

References

Barab, S. A., Squire, K. D., & Dueber, W. (2000). A co-evolutionary model for supporting the emergence of authenticity. *Educational Technology Research and Development*, 48(2), 37-62.

Betz, A., Flake, S., Mierwald, M., & Vanderbeke, M. (2016). Modelling authenticity in teaching and learning contexts. A contribution to theory development and empirical investigation of the construct. In C.-K. Looi, J. Polman, U. Cress, and P. Reimann (Eds.), *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 2* (pp. 815–818). Singapore: International Society of the Learning Sciences.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.

Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator*, 15(3), 6-11.

Gulikers, J. T., Bastiaens, T. J., & Kirschner, P. A. (2004). A five-dimensional framework for authentic assessment. *Educational Technology Research and Development*, 52(3), 67-86.

Gulikers, J. T., Bastiaens, T. J., & Martens, R. L. (2005). The surplus value of an authentic learning environment. *Computers in Human Behavior*, 21(3), 509-521.

Nachtigall, V., Shaffer, D. W., & Rummel, N. (2022a). Stirring a secret sauce: a literature review on the conditions and effects of authentic learning. *Educational Psychology Review*, 34(3), 1479-1516.

Nachtigall, V., Yek, S., Lewers, E., Brunnenberg, C., & Rummel, N. (2022b). Fostering cognitive strategies for learning with 360 videos in history education contexts. *Unterrichtswissenschaft*, 50(4), 615-638.

Shaffer, D. W., & Resnick, M. (1999). "Thick" authenticity: New media and authentic learning. *Journal of Interactive Learning Research*, 10(2), 195-216.

Shaffer, D. W., Collier, W., & Ruis, A. R. (2016). A tutorial on epistemic network analysis: Analyzing the structure of connections in cognitive, social, and interaction data. *Journal of Learning Analytics*, 3(3), 9-45.

Stamer, I., David, M. A., Höffler, T., Schwarzer, S., & Parchmann, I. (2021). Authentic insights into science: scientific videos used in out-of-school learning environments. *International Journal of Science Education*, 43(6), 868-887.



Empowering Learners through Technologies and Preparing them for a Data-driven World

Rotem Israel-Fishelson, University of Maryland, rotemisf@umd.edu

Abstract: To succeed in today's data-driven world, students must have the knowledge and skills to understand and engage with the data and technologies that impact their lives. My research explores ways to empower students with creative thinking and computational thinking skills and impart data science practices. Rooted in constructionist and sociocultural perspectives, my research approach integrates Design-Based Research, Learning Analytics, and Participatory Design to bridge theory and practice and prepare students to be informed, data-literate citizens. My future work will focus on combining participatory design and learning analytics methods to provide a dual prism to the voices of the learners and the underlying learning processes.

Introduction

Data is changing our world. This change necessitates the cultivation of a multifaceted skill set, encompassing not only technical proficiency but also a nuanced understanding of the socio-cultural implications of data and technology (Lee et al., 2021). Students today must be able to think computationally, solve complex problems, and approach challenges with a creative mindset. Computational thinking (CT) is a keystone skill that empowers individuals to define and solve real-world problems using algorithmic methods (Shute et al., 2017). Concurrently, fostering creative thinking becomes indispensable as it encourages students to envision innovative solutions and valuable products (Beghetto, 2019).

Along with creative and computational thinking, students today should be able to analyze, synthesize, and interpret data to derive meaningful insights (Deahl, 2014). Data science and artificial intelligence (AI) underpin these practices and serve as catalysts for innovation and problem-solving. The rapid evolution of these fields requires students to learn continuously and be ready for innovations. This will prepare them for future challenges and position them as active contributors to the technological advancements shaping our world. The significance of data science and AI education extends beyond technical proficiency; it encompasses the development of critical thinking, ethical reasoning, and the ability to make informed decisions in this ever-changing world (Biehler et al., 2022).

My research seeks to understand how to empower students to develop creative and computational thinking skills. I aspire to develop ways to introduce students to the foundations of data science and AI so that they understand and are poised to thrive in the world around them. I am particularly interested in the role of technology in these learning processes, the design of innovative learning environments, the nature of educational activities, the context in which they take place, and how all these factors influence the learners themselves.

Theoretical framework and methods

This research synthesizes constructionist and sociocultural perspectives on learning, drawing from such seminal works as those by Papert (1980) and Nasir et al. (2006). By integrating these frameworks, my research attends not only to the internal cognitive processes involved in learning but also to the broader sociohistorical contexts that shape and inform the learning endeavor. I put a particular emphasis on perceptions of the role technology plays in learners' lives and in mediating hands-on learning experiences. Through rigorous empirical inquiry and interdisciplinary dialogue, I aspire to contribute to cultivating adaptive, innovative, and informed learners.

The overarching framework guiding my investigation is rooted in Design-Based Research (DBR), emphasizing iterative design and analysis cycles to refine theoretical understandings and inform interventions (DBR Collective, 2003). I aim to bridge the gap between educational research and the practical complexities of fostering skills proficiency by grounding my research in the dynamic interplay between theory and practice. Central to my research plan is utilizing Learning Analytics (LA), a powerful method that harnesses data-driven insights to illuminate the intricacies of the learning journey (Berland et al., 2014). LA serves as a diagnostic lens, enabling a nuanced understanding of the multifaceted processes, challenges, and opportunities underpinning skill acquisition. Complementing this quantitative lens, I employ Participatory Design (PD) to inform the design of the learner experiences. PD emphasizes the active involvement of end-users in the design process, empowering them to articulate their values, challenges, and aspirations (DiSalvo et al., 2017). Using this approach, I aim to uncover learners' needs and desires and ensure that their voices are not only heard but actively shape the evolution of educational practices. To date, my research has focused on two main areas: (1) the acquisition of computational thinking and creativity using learning platforms; and (2) situating data science in the lived experiences of students.

Acquisition of creative and computational thinking in game-based platforms

In my doctoral work, I explored the acquisition of CT over time and its relationship with creativity. I applied LA methods and analyzed data from over 300,000 students to examine their persistence, achievement, and difficulty in the CodeMonkey platform. I also conducted two controlled experiments and an intervention program to foster creativity and examined the associations between CT and creativity in the Kodetu platform. Findings showed that students struggle with some CT concepts, and that, surprisingly, younger students more easily perceived abstract concepts such as Arrays compared to their older peers. Additionally, I found that my intervention program led to a significant improvement in measures of CT, creative thinking, and computational creativity among the study population. The study contributed new assessment methods and provided practical recommendations for improving learning platforms and developing mechanisms to support students in solving complex problems.

Situating data science in the digital lives of students

My current research project investigates ways to introduce high school students to the foundations of data science by having them pose interest-driven questions and answer them by writing programs to analyze data from public sources. The program focuses on students from underrepresented communities in computing on the potential negative impact of data/algorithms on their lives. I led the design and execution of a series of participatory design sessions to gain insights into students' interests and their perceptions of the impact of data on their lives. Currently, I am developing an interest-driven introductory data science curriculum and exploring ways to incorporate students' interests and ideas into the learning experiences. This iterative process is being conducted as part of a research-practice partnership (RPP) with teachers and students, which aims to improve learning and prepare students to thrive in our data-rich world.

Future work

In my future work, I aim to develop interventions that advance the body of knowledge and promote essential computational skills in learners. This includes the cultivation of proficiency in data science and AI-based tools while nurturing CT and creative thinking. By leveraging insights from LA and PD, I intend to study and co-create learning platforms and processes that resonate with the needs and preferences of students. This research aligns with the principles of learning sciences, combining rigorous empirical investigation with a responsive and student-centered approach. The utilization of DBR, LA, and PD reflects a commitment to evidence-based practice, ensuring that educational interventions are theoretically grounded and attuned to learners' lived experiences. Through this interdisciplinary and innovative approach, I aspire to contribute valuable insights that inform practice, policy, and the ongoing discourse in the dynamic field of learning sciences.

References

Beghetto, R. A. (2019). Creativity in Classrooms. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge Handbook of Creativity* (pp. 587–606). Cambridge University Press.

Berland, M., Baker, R. S., & Blikstein, P. (2014). Educational data mining and learning analytics: Applications to constructionist research. *Technology, Knowledge and Learning*, 19, 205–220.

Biehler, R., Veaux, R. D., Engel, J., Kazak, S., & Frischemeier, D. (2022). Research on data science education. *Statistics Education Research Journal*, 21(2), 1–1.

DBR Collective. (2003). *Design-based research: An emerging paradigm for educational inquiry*. Educational Researcher, 5–8.

Deahl, E. (2014). *Better the data you know: Developing youth data literacy in schools and informal learning environments* [Master's thesis, Massachusetts Institute of Technology].

DiSalvo, B., Yip, J., Bonsignore, E., & DiSalvo, C. (2017). *Participatory design for learning: Perspectives from practice and research*. Taylor & Francis.

Lee, V. R., Wilkerson, M. H., & Lanouette, K. (2021). A call for a humanistic stance toward K–12 data science education. *Educational Researcher*, 50(9), 664–672.

Nasir, N. S., Rosebery, A. S., Warren, B., & Lee, C. D. (2006). *Learning as a cultural process: Achieving equity through diversity*. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Harvester Press.

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, 22, 142–158.

Acknowledgments

This work was supported by the National Science Foundation under Grant #2141655.



Understanding Student Engagement Through a Sociocultural Lens in Technology-Mediated Learning Environments

Megan Humburg, Indiana University, mahumbur@indiana.edu

Abstract: This paper outlines how I have leveraged sociocultural theories of learning to understand student engagement through a student-centered and multidimensional lens. My work explores how we can analyze the moment-by-moment unfolding nature of engagement in technology-mediated environments in order to contextualize the impact of social and emotional dynamics in learning. My future research will explore learning environments supported by artificial intelligence, to better understand how innovative technologies open up or foreclose opportunities for engaged learning.

Research goals and theoretical framework

My program of research focuses on student engagement, and in particular understanding how learners' emotional experiences, rooted in social and cultural contexts, fundamentally intersect with and impact what and how they learn in technology-mediated environments. Engagement research commonly explores participation and interaction across four dimensions, capturing the behaviors students use to participate in learning tasks (behavioral engagement), the conceptual ideas and disciplinary practices they wrestle with (cognitive engagement), the emotions that are cultivated within and around the activity (emotional engagement), and the quality of collaboration as students learn in community (social engagement). These four dimensions are not static attributes, but rather are a product of interactions between learners and environments (Ryu & Lombardi, 2015). This sociocultural framing of engagement encourages researchers to broadly re-consider what aspects of learners' experiences are relevant by locating emotion and social relationships as core threads within the process of learning rather than external influences. Leveraging my deep knowledge of embodied mixed-reality technologies as well as my growing expertise in AI-supported environments, my research asks scholars and educators to consider how we can design engaging technology-supported learning activities that spark joy, build passion, and guide students through valuable moments of frustration and challenge.

I also work to design and build learning environments that bridge across STEM, arts, and humanities disciplines, reflecting how learners will use their knowledge and skills in the world outside the classroom as well as leveraging the arts and humanities as avenues for sparking interest in STEM for broader audiences of learners. At its core, my work views the learning process as multidimensional and seeks to expand theories, methods, and technologies to better account for the ways learning is embedded in emotional experience, social interaction, and culture. Using the construct of student engagement as an avenue towards the design of more equitable learning activities, I strive to center the needs of disengaged, frustrated, and overlooked learners in particular by focusing on how our designs for learning technologies can reconnect these learners to the joy, curiosity, and community that should, in an ideal world, be inseparable from the learning process.

Building on this commitment, my work has centered on three core strands of research: 1) Understanding how learners' cognitive, behavioral, social, and emotional engagement dynamically build on one another to support learning in collaborative activities (Humburg, 2023; Humburg, 2020; Craig et al., 2020), 2) Exploring how learners' body movements and gestures (i.e., embodiment) can be leveraged as tools for engaged learning (Tu et al., 2023; Danish et al., 2020), and 3) Designing advanced and immersive technologies to support interdisciplinary engagement with a range of disciplines (Humburg et al., 2023; Craig et al., 2021). These three research interests (engagement, embodiment, and technology) have intersected often in my previous work, which has spanned grade levels (elementary, middle grades, and undergraduate students) and disciplinary boundaries (science, history, and music). I have designed curricula and assessments for a variety of technology-rich learning environments, including mixed-reality motion-controlled simulations, game-based learning environments, network analysis tools, and artificial intelligence-driven adaptive narratives. Through my work on these different projects, I have developed a keen sense of how learning technologies integrate into and impact classroom learning environments, and how they can open up or foreclose opportunities for meaningful student engagement.

Methods

The methods I draw upon are centered on sophisticated ways of capturing and analyzing the impact of engagement on the learning process. I mainly leverage qualitative approaches such as interaction analysis (Jordan & Henderson, 1995), thematic analysis (Braun & Clarke, 2012), and content analysis (Krippendorff, 2018) in order to explore the moment-by-moment interactions between students and teachers and how the behavioral, cognitive,



emotional, and social layers of these interactions intersect to influence how and why students engage (or disengage) with learning. I also value integrating these deep qualitative explorations with powerful quantitative approaches so that I can make sense of both overarching interactional patterns and the nuance of particular learning moments.

Contributions and future directions

Looking towards the future, my research agenda will encourage the design of engaging and equitable learning experiences by questioning what aspects of learners' experiences "count" as relevant for learning in technology-mediated environments. For example, do we consider how students learn with and through their bodies, or do we limit our assessments to spoken and written forms of demonstrating understanding? Expanding what kinds of student actions and experiences we consider when analyzing engagement changes what patterns we see, as well as which students are seen. The joys, frustrations, and uncertainties of the learning process can both open and foreclose opportunities for new discoveries, and each new technology we integrate can support and/or interfere with students' learning, agency, dignity, and privacy. My research offers a multifaceted, socioculturally-grounded framework of student engagement in order to highlight power imbalances in learning spaces that prevent students from feeling that their voices are heard and that they are viewed and treated as multidimensional people. In particular, I am currently exploring how AI-supported narrative-centered learning environments can support the emotional and social layers of student engagement as learners navigate through computer-based educational stories. Our team is achieving this by thoughtfully and ethically designing AI-driven conversational agents that can scaffold help-seeking, argumentation, and collaboration in the context of the open-ended, narrative investigation of socio-scientific issues. Designing technological supports that foreground student engagement and student-led inquiry as central to the learning process can help us to move away from technocentric designs for learning so we can carefully consider how the addition of technology shifts and transforms the available opportunities for students to engage with ideas and with each other.

References

Braun, V. and Clarke, V. (2012). Thematic analysis. In Cooper, H., Camic, P.M., Long, D.L., Panter, A.T., Rindskopf, D. and Sher, K.J. (eds.) *APA Handbook of Research Methods in Psychology, Vol. 2: Research Designs: Quantitative, Qualitative, Neuropsychological, and Biological*, American Psychological Association: Washington, DC, pp. 57-71.

Craig, K., Danish, J. A., Humburg, M., Hmelo-Silver, C., Szostalo, M., & McCranie, A. (2021). Net.Create: Network visualization to support collaborative historical knowledge building. *International Journal of Computer-Supported Collaborative Learning*. <https://doi.org/10.1007/s11412-021-09343-9>

Craig, K., Humburg, M., Danish, J. A., Szostalo, M., Hmelo-Silver, C., & McCranie, A. (2020). Increasing students' social engagement during COVID-19 with Net.Create: Collaborative social network analysis to map historical pandemics during a pandemic. *Information and Learning Sciences*, 121(7/8), 533-547.

Danish, J. A., Enyedy, N., Saleh, A., & Humburg, M. (2020). Learning in embodied activity framework: A sociocultural framework for embodied cognition. *International Journal of Computer-Supported Collaborative Learning*, 15, 49-87.

Humburg, M., Dragnić-Cindrić, D., Hmelo-Silver, C., Glazewski, K., & Lester, J. (2023). "Make all teachers robots": How middle schoolers negotiate the possibilities of AI in education. Paper accepted for presentation at the American Educational Research Association (AERA) 2024 Conference.

Humburg, M. (2023). How do we 'see' engagement in a classroom?: A comparison of researcher, student, and teacher perspectives. *Proceedings of the International Conference of the Learning Sciences*, Montréal, Canada.

Humburg, M. (2020). Engagement in Motion: How the Body Mediates Social and Emotional Engagement With Science Learning. In Gresalfi, M. and Horn, I. S. (Eds.). *The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences (ICLS) 2020, Volume 2*, 1039-1046. Nashville, Tennessee: International Society of the Learning Sciences.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, 4(1), 39 - 103.

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. SAGE publications.

Ryu, S. & Lombardi, D. (2015). Coding classroom interactions for collective and individual engagement. *Educational Psychologist*, 50(1), 70-83.

Tu, X., Danish, J., Humburg, M., Zhou, M., Mathayas, N., Enyedy, N., & Jen, T. (2023). Understanding young children's science learning through embodied communication within an MR environment. *International Journal of Computer-Supported Collaborative Learning*. <https://doi.org/10.1007/s11412-023-09395-z>



Bridging Boundaries: Interdisciplinary Learning, Educational Technologies, and Future Workforce Preparation

Joey Huang, North Carolina State University, joeyhuang@ncsu.edu

Abstract: My research intersects design, learning, and educational technology, focusing on (a) Theorizing and designing for interdisciplinary learning, (b) Designing technologies to broaden STEM+C participation, and (c) Upskilling and reskilling for the future of work. This summary outlines past and ongoing research in each theme, demonstrating a commitment to constructionist theory, interdisciplinary collaboration, and a blend of qualitative and quantitative methodologies. Future work includes advancing the theoretical framework for interdisciplinary learning and developing the Research-Practice-Industry Partnerships (RPIP) model to bridge industry collaboration and artificial intelligence in education.

Research summary

My research is centered on the intersection of design, learning, and educational technology. More specifically, it focuses on three themes: (a) Theorizing and designing for interdisciplinary learning, (b) Designing educational technologies for broadening science, engineering, mathematics, and computing (STEM+C) participation, and (c) Upskilling and reskilling learners for future of work. My previous and current work has undergone review and publication in Learning Sciences and Computer-Supported Collaborative Learning (CSCL) venues. In general, my research is mainly grounded in constructionism, and I utilize both qualitative and quantitative methodologies to gather and analyze data. In the following paragraphs, I provide examples within each theme and plans for future research.

Theorizing and designing for interdisciplinary learning

Interdisciplinary approaches in CSCL are crucial for integrating diverse perspectives, with innovative methodologies aiming to achieve this objective (Hmelo-Silver & Jeong, 2021). Despite the compelling argument favoring the incorporation of CSCL practices in classrooms to cultivate workplace-relevant skills, there remains substantial work to facilitate this transition. The literature on interdisciplinarity is vast, yet the definition and concept are still under discussion (Jacobs & Fickle, 2009). Interdisciplinarity is essential for future engineers' core competency, involving the understanding and application of diverse knowledge in designs (Lattuca et al., 2012; National Academy of Engineering, 2004). In my work, I view interdisciplinarity as a skill possessed by an individual, which can be assessed and further developed through collaborative experiences with diverse others. I hypothesize that more interdisciplinary ways to engage in computational thinking (CT) will widen experiences of what counts as rigorous, relevant CT in undergraduate computer science (CS) and, in the process, give future shapers of the computer science industries an understanding that collaboration, diversity, and creativity are essential components of CS fields.

Building on my dissertation and postdoctoral work (Huang & Parker, 2022; Huang et al., 2023), I seek to advance interdisciplinary CS education by merging Robotics and Textiles into a scalable undergraduate curriculum. This curriculum underscores their shared foundation in mathematics and CT, utilizing software as a tangible bridge. Drawing on constructionist theory, embodied cognition, and embodied mathematics (Lakoff & Núñez, 2000), I analyze quantitative and qualitative data from surveys, interviews, and videos to address: (1) the development of interdisciplinarity through positive collaborative learning experiences; (2) the correlation between interdisciplinarity measures, collaboration processes, product quality, and expertise transfer; and (3) challenges hindering interdisciplinarity development. My goal is to deepen insights into embodied CS learning in collaborative settings, fostering cognitive and social engagement. This provides a pathway for those valuing diversity as crucial for long-term sustainability in STEM and beyond.

Designing educational technologies for broadening STEM+C participation

As a learning scientist, my research focuses on how design shapes learning experiences, particularly in addressing equity issues in technology-rich fields. I explore how the choice of tools and materials influences learning possibilities and participant diversity, drawing on Butler's (1990) conceptualization of gender as performance. This perspective highlights how femininities and masculinities emerge within socially constructed communities of practice, where certain activities and tools are associated with specific gender identities, such as sewing with textiles being linked to femininity and building electronics to masculinity. I emphasize the significant impact of tools and materials on participant demographics and acquired knowledge, building on previous initiatives'



marginal improvements in gender representation (e.g., Corbett & Hill, 2015). Through interviews and video data collection, I investigated students' perceptions of STEAM learning and materials, informing the design of tools and curriculum within the project (Huang et al., 2023).

Upskilling and reskilling learners for future of work

In my collaborative efforts with industry partners like Boeing and local welding companies, we developed augmented reality (AR) and virtual reality (VR) learning tools to address upskilling and reskilling needs. Specifically with Boeing, I focused on crafting an advanced online education platform for professional engineers, researching optimal design principles for courses such as Additive Manufacturing. Utilizing learning analytics and integrating machine learning, I analyzed participant engagement, uncovering meaningful patterns in material utilization, trajectories, and proficiencies. This exploration aimed to understand how these platforms equip professional engineers with real-world skills, aligning course objectives with the latest learning sciences research. The results established the design principles aimed at providing effective online learning by establishing the data infrastructure for individual learning. Beyond Boeing, I collaborated with Purdue University engineers to devise a cost-effective, user-friendly AR and VR content creation tool. I conducted interviews and designed content for mixed reality environments. The resulting framework empowers experts to independently generate and modify content, facilitating seamless knowledge transfer to future workforce members (e.g., Zhu et al., 2023).

Future work

My present and upcoming research encompass two novel projects that integrate my three research strands. The initial project focuses on constructing the theoretical framework for interdisciplinarity and interdisciplinary learning in the field of learning sciences. To advance this research avenue, I will collaborate with computer scientists from the Department of Computer Science at North Carolina State University and engineers from Carnegie Mellon University, engaging in ongoing data collection and analysis across states to address the aforementioned research questions regarding interdisciplinary learning. Subsequently, drawing on my experiences collaborating with industry partners, I aspire to formulate a novel model termed Research-Practice-Industry Partnerships (RPIP). This cross-sector, co-design approach to research and development aims to foster the creation of new artificial intelligence that accommodates the complexities of the learning environment. I will collaborate with local industry partners at North Carolina State and learning scientists in this community to further refine the RPIP model.

References

Butler, J. (1990). *Gender trouble: Feminism and the subversion of identity*. London: Routledge.

Corbett, C., & Hill, C. (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. American Association of University Women.

Hmelo-Silver, C. E., & Jeong, H. (2021). An Overview of CSCL Methods. In U. Cress, C. Rosé, A. F. Wise, & J. Oshima (Eds.), *International Handbook of Computer-Supported Collaborative Learning* (pp. 65–83). Springer International Publishing.

Huang, J., Parker, M. (2022). Developing computational thinking collaboratively: The nexus of computational practices within small groups. *Journal of Computer Science Education*.

Huang, J., Cawelti, L., Peppler, K. (2023). Exploring algorithm building through designing and making kinetic sculpture. In P. Blikstein, J. V. Aalst, R. Kizito, & K. Brennan (Eds.) *17th International Conference of the Learning Sciences (ICLS)* (pp. 1494-1497). Montreal, Canada: International Society of the Learning Sciences.

Jacobs, J. A., & Frickel, S. (2009). Interdisciplinarity: A critical assessment. *Annual Review of Sociology*, 35.

Lakoff, G., & Núñez, R. (2000). *Where mathematics comes from* (Vol. 6). New York: Basic Books.

Lattuca, L. R., Knight, D. B., & Bergom, I. M. (2012, June). Developing a measure of interdisciplinary competence for engineers. In *2012 ASEE Annual Conference & Exposition* (pp. 25-415).

Peppler, K., Huang, J. (2023). Visual Learning Analytics to Upskill Aerospace Engineers in Advanced Manufacturing. In P. Blikstein, J. V. Aalst, R. Kizito, K. Brennan (Eds.) *17th International Conference of the Learning Sciences (ICLS)* (pp. 1900-1902). Montreal, Canada: International Society of the Learning Sciences.

Zhu, Z., Liu, Z., Zhang Y., Zhu, L., Huang, J., Villanueva, A., Qian, X., Peppler, K., Ramani, K. (2023). LearnIoTVR: An end-to-end virtual reality environment providing authentic learning experiences for Internet of Things. *The ACM CHI Conference on Human Factors in Computing Systems 2023*.

*Honorable Mention Award



Towards Equitable STEM Participation: Fostering Critical Collaborative Competence in Meaningful Collaborative Processes

Tugce Aldemir, Texas A&M University, taldemir@tamu.edu

Abstract: My research employs technology-assisted collaborative processes and instructional models to empower students and teachers, fostering critical collaborative competence and addressing power dynamics in collaborative settings. I summarize two strands of research that contributed to this trajectory: the development of multicultural collaborative competence in CSCL and horizontalizing power dynamics in co-design processes. My research aims to contribute to the literature by offering theoretical and practical insights into political dynamics in collaborative learning and teaching practices.

Introduction

My research focuses on broadening equitable participation in STEM through empowering students and teachers to become authors of their teaching and learning processes and outcomes (Gutiérrez & Jurow, 2016). To achieve this, I design and analyze technologically-assisted collaborative processes that are meaningful to learners and teachers and instructional models to enhance their critical collaborative competence. Building on Borge et al.'s (2018) definition of collaborative competence as the knowledge, awareness, and ability to regulate collective thinking processes, I define critical collaborative competence as the knowledge and awareness of imbalanced power dynamics in collaborative processes arising due to various factors, such as epistemic hegemony (i.e., domination of one way of knowing), perceived differences in status and authority, coupled with the ability to regulate collective thinking processes to achieve a shared goal. My research draws on sociocultural learning theory, which views learning as a cultural and social phenomenon characterized by understanding, reflecting, and participation shifts. This process is shaped by the context in which it occurs, the norms and interactions in learning environments, and societal power structures and histories that shape these cultural and social dynamics (Vossoughi et al., 2016). Additionally, I draw on group cognition theory, which posits that learning occurs at various scales, including individual, group, and community levels, where interaction among group members can lead to shared understanding and knowledge construction (Stahl, 2006).

Developing and operationalizing a multicultural collaborative competence in CSCL

This project is centered on empowering learners as socio-political agents, enhancing their awareness of the diverse societal positions related to social identities, inequalities, and structural challenges. It aims to foster their ability to develop shared meanings across differences, thus building individual and collective capacities for social change. To achieve these objectives, I have developed and operationalized a theoretically grounded model of multicultural collaborative competence, which I defined as the skills needed to regulate and optimize critical-dialogic discussions to develop shared meanings and interpersonal connections across divergences and commonalities in the context of identity-related politically charged topics. This model identifies communication patterns that facilitate high-quality shared meaning-making in discussions on politically sensitive topics. Additionally, the project examines the interplay between technology-assisted regulatory processes and socio-political dynamics within collaborative settings. Building upon the socio-metacognitive expertise framework by Borge et al. (2018), this study addresses significant gaps in CSCL research, focusing on the impact of sociopolitical factors on power dynamics and socio-emotional exchanges during collaborative learning processes (Uttamchandani et al., 2020). Our previous investigations have explored the regulatory strategies that diverse teams utilize to navigate discussions on politically charged topics. Our goal was to evaluate the feasibility of enhancing intergroup dialogues in CSCL environments where facilitator support is not immediately available (Aldemir et al., 2021). The findings were promising, as the teams exhibited regulatory behaviors aligned with effective facilitation practices. In a subsequent study, we conducted a comparative case analysis to uncover communication patterns and associated behaviors within intergroup dialogues facilitated by CSCL tools and models (Aldemir et al., 2022). We are currently refining this model using data from four semesters of collaborative discussions, employing conversation analysis and comparative case analysis methods. Moving forward, my research will continue to explore avenues for bolstering multicultural collaborative competence within CSCL environments, focusing on leveraging generative AI agents.



Horizontalizing power dynamics in co-design processes

This study was part of a broader NSF-funded project that aimed to develop an integrated high-school STEM biology curriculum, with a focus on bioinformatics, and to provide accompanying professional development activities (#1812738) (Yoon et al., 2023). In this study, we explored the collaborative design processes between teacher and researcher partners, identifying how relational and interactional power dynamics evolved over the course of the partnership and how they influenced equitable/inequitable participation in these collaborative design processes. Through conversation analysis, artifact analysis, and thematic analysis, we discovered that power imbalances and the lack of common language between teachers and researchers (Coburn et al., 2008; Farrell et al., 2019) were mitigated by the facilitation of relationship-building and trust-building strategies. These strategies enabled both parties to willingly engage in equitable practices, contributing to the shared goal of redesigning the curriculum (Aldemir et al., under review). In a follow-up study, which drew from participatory design research (Bang & Vossoughi, 2016), we invited teachers and students who had previously experienced the curriculum in a classroom setting to be co-designer partners in redesigning the curriculum. We explored collaborative dynamics, where an additional layer of power dynamics emerged with the inclusion of students due to the transfer of traditional teacher-student roles from classroom to co-design context and student and teacher partners' conflicting funds of knowledge regarding how the curriculum was practiced and engaged with. The study is currently in progress, and the findings from this study offer significant insights into research-practice partnership literature. They also form the foundation for my future research that will focus on developing and facilitating technology-supported strategies to help students, teachers, and researchers regulate their power dynamics, with the goal of leveraging the varied expertise and funds of knowledge of all partners in collaborative design processes.

Future directions

Building on these two research trajectories, I am interested in leveraging generative AI tools to facilitate safe spaces where learners can practice shared meaning-making around politically charged discussions. Additionally, I am interested in further exploring co-design as a tool for empowering pre-service and in-service teachers in supporting their adaptive expertise in the face of AI-induced expansive learning and teaching possibilities. Lastly, I aim to integrate computational analytical methods into my research methodology to quantify discourse for a more nuanced understanding of political dynamics and collaborative processes.

References

Aldemir, T., Borge, M., & Xia, Y. (2021). Exploration of facilitation strategies for intergroup dialogues in a CSCL context. In *Proceedings of the 14th International Conference on Computer-Supported Collaborative Learning-CSCL 2021*. International Society of the Learning Sciences.

Aldemir, T., Borge, M., & Soto, J. (2022). Shared meaning-making in online intergroup discussions around sensitive topics. *International Journal of Computer-Supported Collaborative Learning*, 17(3), 361-396.

Bang, M., & Vossoughi, S. (2016). Participatory Design Research and Educational Justice: Studying Learning and Relations Within Social Change Making. *Cognition and Instruction*, 34(3), 173-193.

Borge, M., Shiou Ong, Y., & Rosé, C. (2018). Learning to monitor and regulate collective thinking processes. *International Journal of Computer Supported Collaborative Learning*, 13(1), 61-92.

Coburn, C. E., Bae, S., & Turner, E. O. (2008). Authority, status, and the dynamics of insider-outsider partnerships at the district level. *Peabody Journal of Education*, 83(3), 364-399.

Farrell, C. C., Harrison, C., & Coburn, C. E. (2019). "What the hell Is this, and who the hell are you?" Role and identity negotiation in research-practice partnerships. *AERA Open*, 5(2).

Gutiérrez, K. D., & Jurow, A. S. (2016). Social design experiments: Toward equity by design. *Journal of the Learning Sciences*, 25(4), 565-598.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*. MIT Press.

Uttamchandani, S., Bhimdiwala, A., & Hmelo-Silver, C. E. (2020). Finding a place for equity in CSCL: ambitious learning practices as a lever for sustained educational change. *International Journal of Computer-Supported Collaborative Learning*, 15(3), 373-382.

Vossoughi, S., Hooper, P. K., & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review*, 86(2), 206-232.

Yoon, S. A., Shim, J., Cottone, A., Noushad N., Yoo, J., Miller, K. (2023). Professional development for STEM integration: Analyzing bioinformatics teaching through considerations of adaptive expertise and cognitive load. In A. Superfine, S. Goldman, and M. Ko (Eds), *Teacher Learning in Changing Contexts* (pp. 69-90). Routledge Press

Doctoral Consortium



International Society of
the Learning Sciences

Developing the Design Principles of Thinking Routines-Embedded Instruction: A Design-Based Research

Jou-Yin Chen, Language Center, National Central University, rachelchen0105@gmail.com

Abstract: The concept of making thinking visible and utilizing thinking routines has gained widespread acceptance in educational practice. However, there exists a gap between these high-level theoretical principles and their practical application. This study aims to bridge this gap by developing instructional design principles for thinking routines (TRIDPs) through three design-based research (DBR) iterations in a course focusing on social issues in English movies at a Taiwanese university. The 3-phase DBR model and conjecture mapping were aligned to present a detailed design history and a clear trajectory of the evolution of TRIDPs. While data analysis is yet to be completed, preliminary findings showed a promising connection between students' learning outcomes and instructional design, thereby reinforcing the validity of TRIDPs.

Key words: thinking routines, design principles, design-based research, conjecture mapping

Objectives

This study aims to develop thinking routines instructional design principles (TRIDPs) across three design-based research (DBR) iterations. My overarching goal is to make thinking visible and cultivate a thoughtful classroom environment. Hence, I have integrated the use of thinking routines (TRs) (Ritchhart et al., 2011) into my instructional design. TRs are deeply rooted in sociocultural views of learning, such as the enculturation of thinking dispositions (Tishman et al., 1993). TRs served as structures and scaffolds to assist students in externalizing their thinking, executing specific types of thinking moves (TMs), and ultimately enhancing their thinking abilities and fostering thinking dispositions. However, a gap persists between the high-level theoretical principles and their practical application. First, the generality of the concept "making thinking visible" may hinder its testability in local contexts (Sandoval, 2004). Second, prior research on TRs has either focused on teaching innovations or on the intervention effects. Limited information has been provided on how TRs align with instructional design at the curriculum level and how practical knowledge may contribute to theoretical development. Therefore, I aim to develop TRIDPs from an instructional design perspective that derive from theory and are informed by practice.

I chose the DBR methodology because it is well-suited for developing local theories (McKenney & Reeves, 2012) or local instructional theories (Gravemeijer & Cobb, 2006). The research was conducted within the context of an English as a Foreign Language course focusing on social issues depicted in English movies at a Taiwanese university. Throughout this course, four movies rich in social issues were carefully selected, and discussions and critical analyses were conducted on the characters, themes, and social issues depicted in the films. Thinking routines (TRs) were employed consistently throughout the semester to guide students in their analytical processes. The study comprised three iterative cycles implemented in three different classes taught by the same instructor. Each cycle spanned one semester (18 weeks/semester). Iteration 1 (I1) included 12 students, Iteration 2 (I2) included 20, and Iteration 3 (I3) included 24. To conduct a systematic evaluation and capture a clear trajectory of TRIDPs evolution, I aligned 3-phase DBR model (McKenney & Reeves, 2012) and conjecture mapping (Sandoval, 2004, 2014). For the 3-phase DBR model, I integrated McKenney and Reeves's version to create a coherent multiple-cycle design, and Gravemeijer and Cobb's version to derive local instruction theory in the form of design principles. Conjecture mapping was used to specify how the theoretical principle of making thinking visible and the derived TRIDPs are embodied in instructional design and evaluate whether the embodiments led to predicted mediating processes and achieved intended outcome. Through this alignment, Phase I involved conducting problem analysis and literature review to explore the issues to be addressed. Phase II encompassed the proposal and construction of design principles, a conjecture map, and instructional design. In Phase III, empirical testing and evaluation were carried out, leading to revisions in the subsequent cycle.

The high-level theoretical principle was defined as: *Making thinking visible assists articulation of thinking and thus deepens learning*. Then an initial set of TRIDPs were derived from this high-level principle and relevant literature, helping to predict and evaluate both process and product of the design. To test and revise the conjectures, data was collected to assess (1) design conjectures, determining if they led to student artifact creation and observable interactions, and (2) theoretical conjectures, evaluating whether intended outcomes were achieved.

Figure 1 depicts the three iteration cycles. Through these three iterations, a total of six TRIDPs were generated, comprising three initial DPs (DP1-3) and three (DP 4-6) that emerged during the iterations. The initial DPs were derived from theory: DP1: Personally relevant topics of discussion will provide a venue to activate thinking; DP2: Collaborative work and discourse will provide a venue where learners can scaffold and deepen

one another's thinking; DP3: Thinking routines will guide students to externalize their thinking and take thinking moves. The conjecture map was then formulated and enacted in I1. Several issues arose, including students' unfamiliarity with TRs and course misalignments, prompting revisions to the DPs to reflect a curriculum view of DP development. DP3 was revised as "Repeated and adapted use of thinking routines will provide scaffolds and structures to guide students to externalize and take thinking moves." DP4-6 emerged as follows: DP4: Translation of generic thinking moves into context-specific objectives will help communicate thinking and learning objectives to curriculum designers, teachers and students; DP5: Thinking move assessment rubric will assist assessing thinking and learning outcome; DP6: Alignments of course objectives, thinking moves, thinking routines, and assessment will assist evaluating effects of thinking curriculum design. Then, the conjecture map was revised in I2, guiding modifications to the instructional design and data collection process. During Iteration 2, students' writing samples, self-evaluation surveys on thinking, and self-reflections were collected. Positive outcomes were observed in students' writing and survey responses, indicating improvements in their thinking abilities. The emergent themes identified through thematic coding of students' self-reflections provided insights into how TRs and group collaboration facilitated learning. This discovery, coupled with the lack of evidence for observable interaction, prompted further revisions to the data collection process in I3. This included revising self-reflection guidelines and collecting audio recordings of group discussions. While data analysis is ongoing, preliminary findings have revealed that students recognized the benefits of using TRs and appreciated the classroom atmosphere and peer support.

Figure 1
Design-Based Research Iteration Cycles

Iteration 1 (Spring, 2021; 12 students)			Iteration 2 (Spring, 2022; 20 students)			Iteration 3 (Fall, 2022; 24 students)		
Phase 1: Analysis & exploration	Phase 2: Design & Construction	Phase 3: Evaluation & reflection	Phase 1: Analysis & exploration	Phase 2: Design & construction	Phase 3: Evaluation & reflection	Phase 1: Analysis & exploration	Phase 2: Design & construction	Phase 3: Evaluation & reflection
<ul style="list-style-type: none"> Literature review Pilot study 	<ul style="list-style-type: none"> Sketch of conjecture map Identification of DPs (DP1-DP3) 	<ul style="list-style-type: none"> Data collection (students' joint TR products, writing, class observation, focused group interview) Key finding: achieved intended outcome IO1-2 Emergent problems: Students' unfamiliarity of TRs, misalignments of course objectives, TM, TR, and assessment 	<ul style="list-style-type: none"> Problem analysis Literature review 	<ul style="list-style-type: none"> Revised conjecture map Modification of DP3 & development of DP4-6 Revised task design (TR repetition & adaptation) 	<ul style="list-style-type: none"> Revised data collection (students' writing, self-evaluation, written self-reflection, & joint TR products), design of thinking move assessment rubric, focused-group interview Key finding: achieved intended outcome IO3 & IO4 Emergent themes from coding results of students' self-reflection Need more evidence of observable interaction 	<ul style="list-style-type: none"> Problem analysis Literature review 	<ul style="list-style-type: none"> Revised conjecture map Revised task design (increase frequency of TRs usage; TR invention & adaptation) 	<ul style="list-style-type: none"> Revised data collection (self-reflection guidelines adaptation, recording of group TR discussion) Key finding: Emergent themes "classroom ethos" from students' self-reflection coding results

The next step in the research is to complete the analysis of the data collected in Iteration 3, focusing particularly on the interactional data. This data may yield further insights into how and why students perceived the classroom atmosphere and support from the social community they established. Additionally, there is more to explore regarding how and whether learners engaged in thinking moves through social interactions within a TRs-embedded instructional environment. The ultimate objective is to generalize TRIDPs, potentially offering a theoretically and practically robust design framework for those interested in integrating TRs into the curriculum.

References

Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational Design Research* (pp. 17-51). Routledge. <https://doi.org/10.4324/9780203088364>

McKenney, S. E., & Reeves, T. C. (2012). *Conducting educational design research*. London: Routledge.

Ritchhart, R., Church, M., & Morrison, K. (2011). *Making thinking visible: How to promote engagement, understanding, and independence for all learners*. San Francisco: Jossey-Bass.

Sandoval, W. A. (2004). Developing learning theory by refining conjectures embodied in educational designs. *Educational psychologist*, 39(4), 213-223. https://doi.org/10.1207/s15326985ep3904_3

Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences*, 23(1), 18-36. <https://doi.org/10.1080/10508406.2013.778204>

Tishman, S., Jay, E., & Perkins, D. (1993). Teaching thinking dispositions: From transmission to enculturation. *Theory into Practice*, 32(3), 147-153. <https://doi.org/10.1080/00405849309543590>

Understanding Mongolian Nomadic Herders' Learning During Participation in an Adaptation Intervention

Qiuyan Wu, University of Illinois Chicago, qwu41@uic.edu

Abstract: Rangeland degradation and climate change pose significant challenges to Mongolia's unique ecosystems and nomadic herders' livelihoods. Interventions have been implemented in Mongolia to support herders' adaptation. However, it remains unclear how they enhance herders' adaptive capacity. Partnering with a national NGO and a group of herders, this study delves into how and what the herders learn as they participate in an adaptation intervention implemented by the NGO. The analysis is anchored in the concepts of infrastructure, infrastructuring, and consequential learning. Infrastructure describes how the intervention is organized; infrastructuring refers to the work of herders in reorganizing the infrastructure. Consequential learning directs attention to learning that matters for herders. Building on these concepts, this study aims to understand when and how herders engage in infrastructuring during participation in the intervention and how infrastructuring supports consequential learning outcomes. This study engages herders as collaborators in data collection and interpretation.

Background and goals

Mongolia has 70% of its territory classified as rangelands. The vast rangelands are crucial for sustaining the traditional nomadic lifestyle of Mongolian herders. These herders move with their livestock twice or three times a year to find suitable grazing areas. However, they now face significant challenges threatening the sustainability of both the rangelands and their livelihoods. Overgrazing, improper land management, and mining activities have led to rangeland degradation. This problem is further exacerbated by climate change impacts, such as longer winters, shorter summers, warmer temperatures, and changing precipitation. Nomadic herders, dealing with the challenges of rangeland degradation, also confront an increasing intensity and frequency of extreme weather events such as *dzuds* (long, severe winters). In *dzuds*, cold weather and deep snow make forage inaccessible, causing high livestock mortality or even a complete wipeout for many herders. The loss of livestock results in rapid impoverishment and large-scale migration of herders from rural to urban areas where they often become underemployed or unemployed urban poor. In response to these challenges, governmental, non-governmental organizations, and international agencies have implemented interventions in Mongolia to support herders' adaptation. However, it remains unclear how the interventions help enhance herders' adaptive capacity (Upton, 2012). Qualitative studies of interventions often focus on intervention outcomes, falling short of capturing the dynamic process that leads to the outcomes (Fernández-Giménez et al., 2019).

This study dives into the dynamic process from the perspectives and experiences of herders and focuses on outcomes that matter for them. The analysis is grounded in the concepts of infrastructure, infrastructuring, and consequential learning. Consequential learning, historically contingent and future-oriented, leads to outcomes that matter for learners (Gutiérrez & Jurow, 2016). In this study, I analyze what learning outcomes herders consider consequential for their adaptation to sustainability challenges. Building on Star's work (Star & Ruhleder, 1996), I conceptualize infrastructure as the social, techno-material, ideological, and spatial organization of the intervention in which herders participate, and infrastructuring as the process where herders make changes to the infrastructure. Infrastructuring, as demonstrated in existing studies, involves improving or creating alternative infrastructure (Calabrese Barton et al., 2021; Penuel, 2019). This study pays particular attention to the nature of infrastructuring that herders engage in within the intervention context. Three key research questions guide this study: 1) When and how do herders engage in infrastructuring as they participate in the intervention? 2) How does infrastructuring support consequential learning outcomes that matter for herders' adaptation to challenges?

Methodology

This study employs a multi-sited ethnography approach, which is well suited for illuminating the network of relations, interactions, practices, and points of tension (Marcus, 1995). This approach guides my analysis of the infrastructural organization and herders' infrastructuring work across contexts.

I collaborate with the Mongolian National Federation of Pasture User Groups (NFPUG), an NGO in Mongolia, and a group of herders. The NFPUG works with the herders to establish a Pasture User Group (PUG) that aims to engage the herders in collective actions for rangeland management. NFPUG will implement a range of intervention activities, including facilitating the establishment of rangeland use agreements, providing



ecological monitoring training, assisting with legal, technology, and market access, and aiding the PUG in registering as a cooperative. This research will commence along with NFPUG's launch of its intervention project with the PUG and extend over the initial six months.

Multiple sources of data will be collected. To comprehend the infrastructure of the intervention, I will review project documents, training materials, and resources provided to herders. I may also meet with the NFPUG staff and trainers to ensure a more comprehensive understanding. To track herders' infrastructuring work, I will collect video recordings and take field notes at training activities (once a month) and herder group meetings (2 or 3 times each month). After each session, I will conduct unstructured interviews with 2-3 herders, informed by my participant observations. Herders' insider perspectives of their infrastructuring work will be captured by their reflections and discussions in a Facebook group. To understand how consequential learning is supported through infrastructuring, I will conduct two 1-hour semi-structured interviews with eight focal herder participants, one at the beginning and the other at the end of the research period. The first interview seeks to understand herders' historical engagement in interventions, motivations for participating in the current intervention, and desired outcomes. The purpose of the second interview is to gain insights into what and how herders have learned by the interview time and how the learning matters for their adaptation to the challenges they face.

Data analysis will begin as my data collection is underway. Video recordings of the training activities, herder group meetings, and interviews will be transcribed verbatim and translated into English. A Mongolian native speaker, as my research assistant, will help review the raw data and capture the cultural nuances. The analysis begins with segmenting transcripts of training activities and herder group meetings into interaction episodes. Each episode is centered on a particular topic being addressed. These episodes are used as the units of analysis. I attend to the social, techno-material, ideological, and spatial organization of the infrastructure that herders discuss and propose to change. The analysis of unstructured interviews and Facebook posts will help reveal invisible infrastructuring work as well as motivations, values, and struggles behind visible and invisible infrastructuring work. Analysis of the interviews with the focal participants will make explicit what matters for herders and how infrastructuring leads to consequential learning outcomes for individuals and the community. I draw on data analysis methods employed in the grounded theory methodology to identify codes, concepts, and themes (Strauss & Corbin, 1987). Herders are engaged as collaborators in data interpretation. Our collaboration will occur in two forms. We will co-code some of the data, especially Facebook posts and unstructured interviews. For other data, I share preliminary findings with herders and invite their perspectives and input.

Expected findings and contributions

I expect to find that herders engage in infrastructuring by negotiating the balance and integration of local and institutional norms, knowledge, and practices. This process is likely to be contentious. Some infrastructuring work may result in the development of new forms of knowledge and ways of knowing, while others struggle to challenge the status quo. Both instances of infrastructuring hold the potential to yield consequential learning outcomes for herders. Tensions might also occur among herders due to power imbalances. In particular, herders with greater power may engage in infrastructuring to enhance their own access to resources not benefiting others.

The findings of this study could inform the improved design and implementation of interventions that attend to how local people learn within the interventions and support learning outcomes that matter for them. This approach to intervention increases the possibility of achieving effective and sustainable intervention outcomes.

References

Calabrese Barton, A., Greenberg, D., Turner, C., Riter, D., Perez, M., Tasker, T., Jones, D., Herrenkohl, L., Davis, E. (2021). Youth Critical Data Practices in the COVID-19 Multipandemic. *AERA Open*, 7(1), 1–16.

Fernández-Giménez, M., Augustine, D. Porensky, L., Wilmer, H., Derner, J., Briske, D., & Stewart, M. (2019). Complexity fosters learning in collaborative adaptive management. *Ecology and Society*, 24(2), 29.

Gutiérrez, K., & Jurow, A. (2016). Social Design Experiments: Toward Equity by Design. *Journal of the Learning Sciences*, 25(4), 565–598.

Marcus, G. (1995). Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. *Annual Review of Anthropology*, 24(1), 95–117.

Penuel, W. (2019). Infrastructuring as a Practice of Design-Based Research for Supporting and Studying Equitable Implementation and Sustainability of Innovations. *Journal of the Learning Sciences*, 28(4–5), 659–677.

Star, S., & Ruhleder, K. (1996). Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research*, 7(1), 111–134.

Strauss, A., & Corbin, J. (1987). *Qualitative analysis for social scientists*.

Upton, C. (2012). Adaptive capacity and institutional evolution in contemporary pastoral societies. *Applied Geography*, 33(1), 135–141.



“We can be researchers too”: Exploring Teacher Agency Changes in Research-Practice Partnerships

Shuqin Li, Vanderbilt University, Hunan Normal University, shuqi.li.1@vanderbilt.edu

Abstract: Teacher agency is essential to the sustainability of research-practice partnerships (RPPs). However, systematic research on this topic, especially in authoritarian cultural contexts, is limited. This longitudinal case study explores how to support teachers to be agentic within RPPs in China. By investigating changes in teacher agency and uncovering the contributors of those changes, the findings provide valuable insights for the strategic design and implementation of effective RPPs, particularly as they connect to broader cultural norms.

Background and goals

Despite considerable attention paid to the impact of research-practice partnerships (RPPs), there is limited understanding of strategies and tools to support teacher agency in RPPs. RPPs are “long-term, mutualistic collaborations between teachers and researchers that are intentionally organized to investigate problems of practice and solutions for improving outcomes” (Coburn et al., 2013, p.2). Recent studies show that effective RPPs enhance the professional development of teachers and researchers and the quality of teaching and learning (e.g., Arce-Trigatti et al., 2018; Peel, 2021). However, these benefits depends on teachers valuing and engaging in RPPs (Toom et al., 2021). We know from research that several inhibitors may impact teacher agency in the RPPs, such as accountability culture, hierarchies and power relations between university and school (Poulton, 2020; Denner et al., 2019). Moving to consider the specific context, RPPs in China typically follow a top-down model in which teachers are relegated to the role of passive listeners (e.g., Chen, 2020). The marginalization of teachers’ bodies and voices often leads to low engagement and satisfaction (e.g., Liu et al., 2016).

Therefore, the purpose of this longitudinal qualitative case study is to investigate how teachers can be fostered to be agentic within RPPs in China. Specific research questions include: (1) How does teachers’ agency change over time in RPPs? (2) What influences changes in teachers’ agency?

In this study, teacher agency was conceptualized as a dynamic continuum, co-constructed by past experiences, present practices, and future goals. As other researchers have pointed out, teacher agency depends not only on individual capacities but also on the particular work “ecologies” shaped by cultures, structures, relationships, and the flow of time (Priestley et al., 2015, p.3). It involves active shifts at the epistemic, relational, and transformative levels (Lipponen & Kumpulainen, 2011).

Methodology

This RPP project takes place in Central China. Participants include eight primary school teachers ($n = 8$), and five university investigators ($n = 5$). The project incorporates perspectives from narrative inquiry (Clandinin & Connelly, 2000), critical pedagogy and feminism (Luke & Gore, 2014), performance studies (Conquergood, 2013), and Forum Theatre (Boal, 1979). It positions the teachers’ bodies as a place of learning, using an embodied narrative approach to build a performance-based, collaborative learning community (see Liu et al., 2024). During each workshop, we facilitated group discussions, in which teachers collaboratively shared, imagined, created, and acted their emotional struggles in teaching practices. These stories often focus on the tensions between teachers and students, and students’ parents. To better act these roles, teachers observed and inquired into a student or parent, and embody them in the integrated story. At the end of each semester, teachers and investigators organized Forum Theatre, where teachers performed a stories on the public stage. What makes this performance unique is that it provides opportunities for other teachers to step in and replace any of the roles at any time. In other words, all teachers are afforded the chance to replay and rehearse their teaching practice, thus fostering body-mind reflection and empowering themselves to undertake actions in the future.

Data were collected from 31 workshops and three Forum Theatre performances, within four semesters (2022-2023). There are three type of data: (1) audio and video transcriptions of the workshops and Forum Theatre performances; (2) teachers’ journals, monologues, and artwork artifacts; and (3) investigators’ observation notes, journals, multiple-round reflections on teachers’ data. All data was transcribed and entered into Nvivo 12 for coding, categorizing, and theorizing (Saldaña, 2016; Merriam, 2015). The data analysis is guided by the ecological perspective of teacher agency, with a specific focus on changes in teachers’ agency in different periods and the ecological factors contribute to such changes.

Preliminary findings

Data analysis is ongoing, and initial results show significant changes in teacher agency, demonstrated by: (1) positioning themselves from passive participants to active researchers; (2) disclosing and reflecting their emotional vulnerabilities; (3) rebuilding relationships with the challenging students and parents. These changes arise from: (1) Iterational factors: teachers' previous experiences in teacher training programs; personal life experience. (2) Practical-evaluative factors: negotiating roles in RPPs with teachers; acknowledging the role of the body; mutual sharing reflection notes. (3) Projective factors: co-creating a book for this RPPs project (short-term goal); discovering more possibilities of education (long-term goal).

Expected contributions

These findings provide valuable insights for educational researchers and practitioners in building sustainable RPPs. Employing a series of methods, such as empowering teachers' roles as researchers, valuing the body as a place for learning, and conducting ongoing dialogue is crucial for encouraging teachers to be agentic. Additionally, by identifying the cultural characteristics of teacher agency in the Chinese context, this study may also enrich the global discourse on teacher agency in RPPs.

References

Arce-Trigatti, P., Chukhray, I., & López Turley, R. (2018). Research-practice partnerships in education. In B. Schneider (Eds.), *The Handbook of Sociology in Education in the 21st Century* (pp. 561-579). Springer International.

Boal, A. (1979). *Theatre of the Oppressed*. Pluto.

Chen, X. (2020). Teacher learning in boundary-crossing lesson study. *Journal of Educational Studies*, 16(2), 47-58. <https://doi.org/10.14082/j.cnki.1673-1298.2020.02.005> (In Chinese)

Clandinin, D. J., & Connelly, F. M. (2000). *Narrative Inquiry: Experience and Story in Qualitative Research*. Jossey-Bass Publishers.

Coburn, C. E., Penuel, W.R., & Geil, K. E. (2013), *Research-Practice Partnerships: A Strategy for Leveraging Research for Educational Improvement in School Districts*. William T. Grant Foundation.

Conquergood, D. (2013). *Cultural struggles: Performance, ethnography, praxis*. University of Michigan Press.

Denner, J., Bean, S., Campe, S., Martinez, J., & Torres, D. (2019). Negotiating trust, power, and culture in a research-practice partnership. *AERA Open*, 5(2), 1-11.

Liu, X., Li, S., & Yang, S. (2024). "It keeps us in solidarity": embodied narrative in Chinese teacher education. *Text and Performance Quarterly*, 1-24.

Liu, H., Liu, C., Chang, F., & Loyalka, P. (2016). Implementation of teacher training in China and its policy implications. *China and World Economy*, 24(3), 86-104.

Lipponen, L., & Kumpulainen, K. (2011). Acting as accountable authors: Creating interactional spaces for agency work in teacher education. *Teaching and Teacher Education*, 27(5), 812-819.

Luke, C., & Gore, J. (2014). *Feminisms and critical pedagogy*. Routledge.

Peel, K. L. (2021). Professional dialogue in researcher-teacher collaborations: Exploring practices for effective student learning. *Journal of Education for Teaching*, 47(2), 201-219.

Poulton, P. (2020). Teacher agency in curriculum reform: The role of assessment in enabling and constraining primary teachers' agency. *Curriculum Perspectives*, 40(1), 35-48.

Priestley, M., Biesta, G. J. J., & Robinson, S. (2015). *Teacher Agency: An Ecological Approach*. Bloomsbury Academic.

Toom, A., Pyhälö, K., Pietarinen, J., & Soini, T. (2021). Professional agency for learning as a key for developing teachers' competencies?. *Education Sciences*, 11(7), 324.

Acknowledgments

This work was supported by China Scholarship Council (Grant No.: 202306720032). I also want to express my sincere gratitude to Prof. Ilana Horn, Prof. Xiangyan Liu, and Prof. Xu Liu for their invaluable insights and suggestions.



Narratives in Augmented Reality Game-based Learning

Kevin Palzer, Media-Based Knowledge Construction, University of Duisburg-Essen, kevin.palzer@uni-due.de,
Supervisor: Daniel Bodemer

Abstract: This dissertation project investigates the impact of narratives within game-based learning (GBL) in augmented reality (AR) environments. Three studies were conducted to derive design recommendations for the development of educational games in AR. Preliminary results indicate that narratives should match the learning content to avoid increasing extraneous cognitive load. In addition, narratives should be related to the application context and areas of personal interest while avoiding negatively associated circumstances such as social pressure to improve the learning experience and outcomes. Further studies should explore the interplay of narrative and interactive elements in educational AR games to provide design recommendations for optimizing learning experiences in both classroom and leisure settings.

Introduction

Learning with interactive and new technologies contributes to creativity and interaction in the learning process and affects the learning experience by enabling learners to engage personally and immersively with the learning subject (Pellas et al., 2019). The positive impact of augmented reality (AR) and game-based learning (GBL) on encouraging knowledge acquisition, interest, motivation and engagement has been identified, although little is known about their combination as ARGBL (Pellas et al., 2019; Yu et al., 2022). The combined representation of physical and virtual elements in AR creates new learning environments that must be effectively contextualized, as their perception is crucial to learning (Krüger et al., 2019). One way to contextualize learning environments in GBL is the narrative of the game, which can be understood as the background story that structures the learning environment by embedding scenarios and contexts, enabling a coherent connection of different game elements such as feedback (Dickey, 2020). Thus, intense and engaging learning experiences can be created that have positive effects on motivation and encourage players to return to the game. Narratives in games allow the learning situation and content to be connected in a way that is seen as meaningful and personally valuable through authentically mediated learning material, interactive and contextual learning environments (Barab et al., 2010). Narrative-centered learning environments can transport players to other places and times through compelling characters that they experience as immersive and real, and they can empower players to take an active role in which they can act, draw conclusions, and experience emotions that encourage active learning (Mott et al., 1999). By providing new ways of interacting with virtual 3D material embedded in the physical environment, ARGBL offers authentic learning environments that can convey abstract and complex content and make invisible information visible (Pellas et al., 2019). Thus, ARGBL provides rich learning experiences that have the potential to enhance learning more effectively in combination than separately. The question that the research in this dissertation project aims to examine is: How should educational AR-games be designed in terms of their narrative and contextual composition to support interactive learning in different domains?

Methods

Three studies were conducted to investigate this question and derive design recommendations for educational AR games. Each study addresses different learning subjects and aspects of GBL elements and AR in education. All studies were laboratory studies with a 2×2 between-subjects design in which quantitative data on motivation, immersion, cognitive load, workload, and learning outcomes were collected to examine the effects on these using two-way ANOVAs for main and interaction effects. Data collection for study 2 and 3 has not yet been completed.

Study 1 ($N = 40$) focused on contextualizing AR environments by using different narrative scenarios and adding physical artifacts to the learning environment. In the narrative, participants were asked to imagine that they were learning either during a medical internship (application context) or during a university course (education context) while interacting with the anatomical AR learning material on a head-mounted display (HMD). In addition, the virtual learning material was either projected onto an additional person (physical artifact presence) or freely projected into the room (physical artifact absence). The application displayed a virtual 3D anatomy model whose parts were described and explained in terms of their functions and processes on a virtual board.

Study 2 ($N = 71$) investigates the influence of a mystery narrative and the integration of terms according to the learners' interest or disinterest while learning Spanish as a second language. Participants are given nine mandatory tasks that teach them vocabulary and grammar. After completing the mandatory tasks, they can complete nine additional tasks on a voluntary basis.



Study 3 ($N = 107$) focuses on the use of a narrative and different types of feedback when learning about edaphology in an educational AR game on an HMD. Participants receive either outcome-oriented feedback (information only about the correctness) or process-oriented feedback (additional detailed and supportive information) within the game and either a fictional narrative about an alien threat is embedded in the game or not. The game has two levels dealing with different topics of edaphology. In both levels, players must explore the environment and interact with various objects to obtain further information, draw conclusions, and thus achieve the learning goals of the game.

Preliminary findings and expected contributions

Through these three studies, different influences of GBL elements and AR environments on learning and related constructs in different subject areas could be found. It was shown that narratives that convey an application context in comparison to an education context (study 1) and those that are enriched with content that corresponds to learners' interest (study 2) led to higher learning outcomes. It can be assumed that the application context is perceived as more meaningful and that enriching the narrative with personally interesting content positively influences how valuable the learning content appears (Barab et al., 2010). It was demonstrated that a narrative is an essential element to effectively bring learners' topics of interest into the learning task, as simply adding these topics had no impact on the learning outcomes (study 2). However, the narrative could not only reinforce positively associated elements and thus support learning, but also reinforce negatively associated circumstances and thus inhibit learning. Thus, it was shown that the projection of virtual anatomical models onto a person did not lead to a meaningfully perceived learning context that supported learning, but led to frustration, which prevented the positive influence of a narrative application context (study 1). This could be due to the person being perceived as an observer and causing social stress, which affected learning outcomes negatively (Kushnir, 1986). Although we could show that process-oriented feedback led to higher learning outcomes and immersion than outcome-oriented feedback, the narrative had no reinforcing effect (study 3). The narrative only had a negative impact on the working memory load by increasing the extraneous load. Learners stated that the context of the narrative did not align well with the learning content, which did not result in a coherent and authentic learning experience and thus potentially put additional strain on working memory.

These preliminary results emphasize the importance and versatility of effective narrative design in educational AR games in different domains. Accordingly, narratives should match the learning content to a certain extent, include an application context and areas of personal interest. In addition, consideration should be given to avoiding negative associated circumstances such as social stress and frustration. Further studies should investigate when and how interactive learning elements can be supported by narratives to positively impact the learning process and thus derive recommendations for the design of appropriate learning experiences for classroom and leisure use.

References

Barab, S. A., Gresalfi, M., Dodge, T., & Ingram-Goble, A. (2010). Narratizing disciplines and disciplinizing narratives: Games as 21st century curriculum. *International Journal of Gaming and Computer-Mediated Simulations*, 2(1), 17–30. <https://doi.org/10.4018/jgcms.2010010102>

Dickey, M. D. (2020). Narrative in game-based learning. In J. L. Plass, R. E. Mayer, & B. D. Homer (Eds.), *Handbook of game-based learning* (pp. 283–306). The MIT Press.

Krüger, J. M., Buchholz, A., & Bodemer, D. (2019). Augmented reality in education: three unique characteristics from a user's perspective. In M. Chang, H.-J. So, L.-H. Wong, F.-Y. Yu, & J.-L. Shih (Eds.), *Proceedings of the 27th International Conference on Computers in Education* (pp. 412–422). Asia-Pacific Society for Computers in Education.

Kushnir, T. (1986). Stress and social facilitation: The effects of the presence of an instructor on student nurses' behaviour. *Journal of Advanced Nursing*, 11(1), 13–19. <https://doi.org/10.1111/j.1365-2648.1986.tb01215.x>

Mott, B. W., Callaway, C. B., Zettlemoyer, L. S., & Lester, J. C. (1999). Towards narrative-centered learning environments. In M. Mateas & P. Sengers (Eds.), *Proceedings of the 1999 AAAI fall symposium on narrative intelligence* (pp. 78–82). The AAAI Press.

Pellas, N., Fotaris, P., Kazanidis, I., & Wells, D. (2019). Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning. *Virtual Reality*, 23(4), 329–346. <https://doi.org/10.1007/s10055-018-0347-2>

Yu, J., Denham, A. R., & Searight, E. (2022). A systematic review of augmented reality game-based Learning in STEM education. *Educational Technology Research and Development*, 70(4), 1169–1194. <https://doi.org/10.1007/s11423-022-10122-y>



Interdisciplinary Dialogic Argumentation and Change in Epistemic Practices among Science Teachers

David Perl-Nussbaum, Weizmann Institute of Science, Davidper@weizmann.ac.il

Abstract: The importance of engaging learners in deliberative argumentation, in which competing perspectives are respectfully yet critically examined, has been recognized in science education. This practice is difficult to achieve due to the compartmentalized structure of traditional science teaching, though. This dissertation explores the conditions for fostering interdisciplinary dialogic argumentation among science teachers and the ways in which such dialogue can enhance epistemic practices in a group. It focuses on the encounter between physics teachers from different disciplinary backgrounds in a professional development program and offers a professional development approach that encourages each group to draw on their disciplinary epistemic practices and engage in deliberative argumentation in a physics context. We are currently developing a coding instrument to examine dialogic and epistemic aspects of teacher discourse to account for deliberation through the integration of different disciplinary epistemic practices.

Introduction

Deliberative argumentation is characterized as a collaborative yet critical search for understanding, taking multiple perspectives into account (Felton et al., 2022). The importance of engaging learners in such discourse has been recognized in the learning sciences and in particular in science education (Osborne, 2010). This idyllic goal meets an educational realm that impedes such interactions. Specifically, the compartmentalization of the scientific disciplines in schools leads each discipline to focus on a narrow set of epistemic practices, i.e., practices related to the construction, justification and evaluation of knowledge (Kelly, 2016). We conjecture that true deliberation in science education contexts can be supported by interdisciplinarity, combining perspectives and reasoning styles from across disciplines to resolve complex problems.

This research focuses on the school disciplines of physics and biology. Physics learning is concerned with abstract, simplified systems that are modeled on the basis of theoretical laws and therefore invite predictive, quantitative reasoning. In contrast, the systems studied in school biology are complex, models are mostly empirical and reasoning is mostly qualitative-descriptive (Redish & Cooke, 2013). This situation makes genuine deliberation, in which alternative models compete, almost impossible in monodisciplinary science classrooms.

Educational context

The study is set in a PD program for middle school physics teachers, many of whom are out-of-field (OOF) teachers with a background in biology. OOF teachers are teachers who teach subjects for which they have no academic major or certification. OOF teaching is a global educational challenge, highly prevalent in middle-school math and physics and in low socioeconomic status schools (Hobbs & Törner, 2019). We propose an approach to the PD of OOF and in-field teachers that encourages each group to draw on their disciplinary resources. We rely on both general principles for productive engagement and specific guidelines for promoting dialogic argumentation among the different teachers (Koichu et al., 2022) to offer design guidelines for interdisciplinary dialogic argumentation activities that would create opportunities for teachers to learn from their collaborative dialogues (Horn & Kane, 2015).

Research goal

This study investigates the encounter between physics teachers from different disciplinary backgrounds in a PD program designed to foster interdisciplinary dialogic argumentation. Specifically, in the context of physics and biology, we expected learners to apply a wide range of epistemic practices, integrating empirical justifications with theoretical, mathematical reasoning. The goal of the research is to explore the relationships between the antecedents of the argumentative activities, the type of dialogue that develops between teachers, and the outcomes - i.e., the enrichment of epistemic practices (Asterhan & Schwarz, 2016). We hypothesize that the epistemic diversity of learners, together with an instructional design that fosters deliberative argumentation, would result in scientific argumentation that is dialogic and rich in disciplinary perspectives and epistemic practices.

Methods and preliminary findings



The first stage of the dissertation was dedicated to the materialization of our design guidelines in PD activities and the in-depth examination of the discourses among teachers in these activities (Perl-Nussbaum et al., 2023). We adopted a case study approach and used the Actor-Network methodology to identify how the educational design helped shape interactions and power relations among the teachers. The analysis illustrated the nuanced ways in which OOF and in-field teachers engage in expansive interdisciplinary dialogic argumentation that not only relies on disciplinary formalisms (formulas and laws), but also considers the complexity of real-world phenomena and applies empirical justifications. The case study provides a qualified success of the effort to create a dialogical space between science teachers from different disciplinary backgrounds in a PD program.

Based on these promising results, we have moved on to the second phase of the study. We are now developing a quantitative coding scheme that aims to capture interdisciplinary dialogic argumentation in the sciences by examining the dialogic moves along with the epistemic practices that teachers enact in their discourse. We are testing the ability of the coding scheme to capture deliberative, epistemically rich dialogues in science and examine their antecedents in a way that is comparable across many groups.

The data collected include the discourse of more than 30 teacher triads who participated in two argumentative activities in our PD program in 2021-2024. 18 groups were heterogeneous (i.e., in-field and OOF teachers together) and 14 were homogeneous. To characterize the type of dialogue among teachers, we relied on Felton and colleagues' (2022) coding scheme, which aims to capture deliberative argumentation among learners. The coding scheme was simplified to reduce the number of codes and to ensure reliability and coherence with other existing dialogic coding tools. To account for the scientific epistemic practices applied in the course of the dialogues, we focused on the different sources that teachers use to justify their claims. Our categories include authority, empirical, theoretical, factual, intuition and unknown, and are still being negotiated. By applying both the dialogic and epistemic schema, we can examine the effects of group composition (heterogeneous vs. homogeneous) on the type of discourse that emerges and on the epistemic practices employed. By juxtaposing the two coding schemes, we wish to examine whether the dialogic deliberativity of the discourse in the interdisciplinary groups also influences the epistemic aspects, i.e. leads to enhancement of epistemic practices.

Expected contribution

The significance of this work is both theoretical and practical. The results of this study would improve our understanding of the epistemic practices of science teachers from different disciplinary backgrounds and the relationships between argumentation and epistemic development. The practical contribution lies in the design and implementation of a novel approach to the professional development of OOF teachers, that capitalizes on the epistemic diversity in the group. Reports from teachers who have already participated in our program (N~180) indicate that this approach has already had an impact on their classroom practice.

References

Asterhan, C. S., & Schwarz, B. B. (2016). Argumentation for learning: Well-trodden paths and unexplored territories. *Educational Psychologist*, 51(2), 164-187.

Felton, M., Crowell, A., Garcia-Mila, M., & Villarroel, C. (2022). Capturing deliberative argument: An analytic coding scheme for studying argumentative dialogue and its benefits for learning. *Learning, Culture and Social Interaction*, 36, 100350.

Hobbs, L., & Törner, G. (Eds.). (2019). *Examining the phenomenon of “teaching out-of-field”: International perspectives on teaching as a non-specialist*. Springer.

Horn, I. S., & Kane, B. D. (2015). Opportunities for professional learning in mathematics teacher workgroup conversations: Relationships to instructional expertise. *Journal of the Learning Sciences*, 24(3), 373-418.

Kelly, G. (2016). Methodological considerations for the study of epistemic cognition in practice. *Handbook of epistemic cognition*, 393-408.

Koichu, B., Schwarz, B. B., Heyd-Metzuyanim, E., Tabach, M., & Yarden, A. (2022). Design practices and principles for promoting dialogic argumentation via interdisciplinarity. *Learning, Culture and Social Interaction*, 37, 100657.

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *science*, 328(5977), 463-466.

Perl-Nussbaum, D., Schwarz, B. B., & Yerushalmi, E. (2023). Interdisciplinary dialogic argumentation among out-of-field and in-field physics teachers. *Science Education*, 107(6), 1457-1484.

Redish, E. F., & Cooke, T. J. (2013). Learning each other's ropes: negotiating interdisciplinary authenticity. *CBE—Life Sciences Education*, 12(2), 175-186.

Acknowledgements

This study was supported by the Israel Science Foundation, grant number 2099/22.



Understanding Longitudinal Teacher Learning across Co-Design and Enactment of Curricular Materials

Katarzyna Pomian Bogdanov, Northwestern University, kpomian@u.northwestern.edu

Abstract: Teachers experience a disconnect between how they were taught and the new ways in which current science reforms are asking them to teach (NASEM, 2015; NRC, 2012; NGSS 2013). At the same time, there are new and promising forms of professional development, including co-design through which teachers and researchers design curricular materials informed by their unique areas of expertise (e.g. Penuel et al., 2022). In this dissertation, I investigate how four science teachers deepen their pedagogy over three years while navigating the challenges of shifting classroom practices through their involvement in the co-design and implementation of curricular materials. This dissertation will produce a view of longitudinal teacher learning to reveal how these novel professional learning environments can help teachers teach more authentically while shifting their teaching in light of the goals of current reforms.

Background and goals of the research

In the United States, The National Research Council (NRC) set forth *A Framework for K-12 Science Education* (Framework) (NRC, 2012) based on which educators and scientists developed the *Next Generation Science Standards* (NGSS) specifying what students should know and be able to do in science (NGSS, 2013). The reforms envisioned by the NGSS pose considerable challenges in the scope and types of changes required of teachers (NRC 2015). An avenue that researchers and policymakers have proposed to help address these challenges is to embody key elements of reform in *curriculum materials* and work with teachers to bring them into their own classrooms (NRC, 2015). One promising new way teachers can engage with curriculum materials is through co-design, which has been shown to help teachers deepen their pedagogical strategies to achieve reforms (e.g. Penuel et al., 2022). But ultimately the most intimate work teachers do with curricular materials is through enactment (e.g. Remillard, 2005; Sherin & Drake, 2009). Importantly, teachers differ in how they take up and translate curricular materials (Philip, 2019), and these differences are influenced by their knowledge, values, and practices (e.g. Barni & Benevene, 2019). Therefore, we must look at how teachers enact the curricular materials and customize them for their own science teaching (Sherin & Drake, 2009). In this dissertation, I conduct case studies of teachers involved in these two key science teacher-learning contexts a) the setting of co-design and b) the setting of classroom enactment.

Much previous research has looked at specific workshops or classrooms without tracking teacher learning across contexts. In contrast, this dissertation takes an in-depth look at how shifts in teacher knowledge occur over a longer time and across multiple contexts (co-design and enactment). I will seek to document how teachers leverage their evolving understanding across different spaces and ultimately how that is reflected in their classrooms. A goal will be to develop a framework that tracks teachers' pedagogical shifts across time and contexts and focus on how teachers tailor the curriculum they design for their own use. The ultimate goal is to produce a true longitudinal cross-contextual analysis of four case studies.

Methodology

This dissertation follows four high school teachers in an effort to more deeply understand how their thinking and practices shift over three years of designing and enacting curriculum materials. I apply a mixed methods approach: a combination of qualitative analysis methods of multiple case studies (Yin, 2013) rooted in grounded theory (Glaser & Strauss, 2017) alongside complementary learning analytics (Martin & Sherin, 2013) across three interrelated dissertation papers. In the first paper, I examine how teachers' pedagogical attitudes and beliefs influence their participation in co-design meetings in which they worked with researchers and other teachers to design novel curriculum units reflecting current reforms. The second paper investigates how these pedagogical beliefs play out as teachers enact the units they co-designed. The third paper examines the longitudinal pedagogical shifts occurring across the two learning contexts (co-design and enactment) over three years. I provide an analysis of teacher learning across various contexts in terms of a framework that captures the values teachers rely on to make decisions while designing and enacting. Ultimately, I seek to demonstrate the framework's analytical properties by using it to track teacher thinking and learning over the three years of the study.

Preliminary and expected findings



In paper 1, I leverage conceptual frameworks of teacher knowledge as attitude, beliefs, and values (e.g. Barni & Benevene, 2019) to develop a *curricular values framework* that a) characterizes *design dilemmas* as moments when a design team encounters multiple ways in which they can proceed with the design process and b) identifies *curricular values* that underlie criteria used to make design decisions (Pomian Bogdanov, 2022). This framework focuses on unpacking key mechanisms to track and conceptualize changes in teacher thinking and learning – having both conceptual and analytical properties. I demonstrate its use as an analytical tool by applying it to two co-design settings – virtual and in-person – to characterize teacher learning shifts over the course of their involvement in these settings.

In paper 2, I apply my *curricular values framework* alongside conceptual frameworks that work to understand adaptations teachers make to curricular materials (e.g. Drake & Sherin, 2006) and frameworks that focus on the participatory relationships teachers have with curriculum and contexts (e.g. Remillard, 2005). These frameworks will help guide my investigation of how science teachers use written curricular materials throughout planning for, enacting, and reflecting on the curriculum they are using. I focus on customizations these co-design teachers make when planning and enacting these units to understand a) the different types of adaptations, b) the motivations that lead to them, c) the values that justify them, and d) the dilemmas teachers face in making them.

In paper 3, I build on papers 1 and 2 to explore longitudinal changes in teacher thinking and learning by tracking important continuities and shifts in teacher knowledge through co-designing and enacting curricular materials. Drawing on a model of conceptual change (Duit & Treagust, 2003) I demonstrate how teachers grapple with deeper shifts in their knowledge and practices over three years and across different teacher-learning experiences.

Expected contributions

Together these papers examine science teacher learning over three years while navigating two promising settings – the innovative professional learning environment of co-design and the situated setting of enacting the designed units. I contribute to theorizing about the complex participatory relationships teachers have with the curriculum (e.g. Remillard, 2005), through a longitudinal cross-contextual multi-case-study view that will further expand these understandings. The conceptual and analytical framework I develop will deepen the field's understanding of teacher thinking and learning. Finally, I contribute to theories relating to teachers' use of curricular materials in their classrooms (e.g. Sherin & Drake, 2009), specifically growing the fields' understanding of adaptations made by *science* teachers and motivations for them in relation to instructional contexts.

References

Barni, D., Danioni, F., & Benevene, P. (2019). Teachers' self-efficacy: The role of personal values and motivations for teaching. *Frontiers in Psychology*, 10, 1645.

Glaser, B.G., & Strauss, A.L. (2017). *The discovery of grounded theory: Strategies for qualitative research*. Routledge.

Martin, T., & Sherin, B. (2013). Learning analytics and computational techniques for detecting and evaluating patterns in learning: An introduction to the special issue. *Journal of the Learning Sciences*, 22(4), 511-520.

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. National Research Council.

National Research Council. (2015). Guide to implementing the Next Generation Science Standards. Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The NAP.

Penuel, W. R., Allen, A.-R., Henson, K., Campanella, M., Patton, R., Rademaker, K., Reed, W., Watkins, D., Wingert, K., Reiser, B., & Zivic, A. (2022). Learning practical design knowledge through co-designing storyline science curriculum units. *Cognition and Instruction*, 40(1), 148-170.

Philip, T. M., Souto-Manning, M., Anderson, L., Horn, I., Carter Andrews, D. J., & Varghese, M. (2019). Making justice peripheral by constructing practice as "Core": How the increasing prominence of core practices challenges teacher education. *Journal of Teacher Education*, 70(3), 251–264.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research*, 75, 211–246.

Sherin, M. G., & Drake, C. (2009). Curriculum strategy framework: investigating patterns in teachers' use of a reform-based elementary mathematics curricula. *Journal of Curriculum Studies*, 41, 467–500.

Yin, R K. (2013). Validity and generalization in future case study evaluations. *Evaluation*, 19(3), 321-332.



Designing Multimodal Expert Feedback in Team-based Simulations

Daniel Sánchez, University of Oslo, daniel.sanchez@iped.uio.no

Abstract: This study examines the use of Multimodal Learning Analytics (MMLA) in nursing education, specifically in simulation-based learning, to enhance student understanding and use of feedback. It focuses on the integration of expert and MMLA-based feedback by nursing teachers. Conducted at a Scandinavian University, the study applies design-based research and collects data from multiple sources in simulations, debriefings, reflection sessions, and co-design meetings. Preliminary results show that students understand and value precise, contextually relevant, goal-oriented multimodal feedback and are able to apply it in following simulations when the feedback is actionable.

Introduction and background

The integration of Multimodal Learning Analytics (MMLA) into higher education represents a significant advancement in enhancing feedback mechanisms, particularly in the context of simulation-based learning such as Intensive Care Unit (ICU) simulations in nursing education. MMLA's ability to utilize diverse data types is instrumental in capturing intricate details within these complex learning settings (Blikstein & Worsley, 2016). Meanwhile, simulation-based learning bridges the gap between theory and practice, providing students with a controlled yet realistic environment to equip nursing students for real-world challenges (Pedersen et al., 2019). However, a significant challenge persists in enabling nursing students to interpret and apply feedback derived from the rich, multimodal data these simulations can provide. This gap is essential, as the value of feedback lies in its comprehension and application by learners (Winstone et al., 2017).

To address this challenge, the study draws on extensive research on expertise. It views expert-driven feedback as observations and guidance typically provided by experienced practitioners, adept at distinguishing relevant patterns and actions often overlooked by novices. Such feedback is pivotal in deliberative practice, a framework emphasizing the need for timely and targeted feedback with opportunities for iterative practice to foster skill development and refine student performance (Ericsson, 2018). Consequently, the MMLA-based feedback, which is the output from interpreting and analyzing data from various sources and presenting it by combining multiple modalities, is tailored to emulate the nuanced guidance of expert-driven feedback. This approach is termed MMLA-based expert feedback.

The core of this research lies in integrating expert feedback with MMLA within nursing education simulations. This endeavor seeks to harmonize technological advancements with deep domain-specific insights, thus creating a robust feedback mechanism that supports student learning and performance.

Research questions

The research project revolves around three key questions:

- (1) How do subject matter experts (nursing teachers) generate feedback on student performance in nursing team-based simulations?
- (2) How do nursing teachers integrate expert-driven feedback into MMLA-based feedback within the context of an ICU simulation training?
- (3) How do nursing students interpret and utilize the MMLA-based expert feedback in their learning and skill development during the ICU simulation?

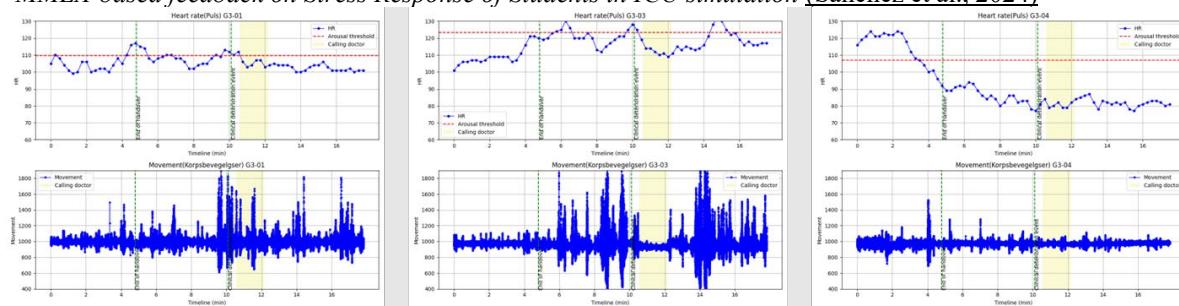
Methodology

This study, part of a larger multimodal learning analytics project, was conducted within a Scandinavian University's nursing course involving an Intensive Care Unit (ICU) simulation. The course aims to enhance student skills in communication, teamwork, patient assessment, and stress response. A Design-Based Research approach (McKenney & Reeves, 2012) guided the study through three iterative stages: Analysis and Exploration, Design and Construction, and Evaluation and Reflection. The following describes the first iteration: (1) *Co-design Meetings*: Meetings with nursing teachers were held to understand the learning context and identify key learner interactions and behaviors in nursing practice. These meetings helped select appropriate sensors, analytics, and feedback mechanisms, which the nursing teachers also validated. The elicitation process that guided the aspects to provide feedback, as well as the selection of sensors and analytics, is explained in Sánchez et al. (2024). (2) *Simulation Sessions*: Multimodal data collected during these sessions included video recordings, audio

captured through unidirectional microphones in headsets, and physiological monitoring using eq02+ LifeMonitor. Audio recordings were transcribed and coded with the help of an experienced nurse. Key moments were turned into video clips with captions and coded transcripts. Stress indicators such as heart rate and body movement were plotted (see Figure 1), utilizing a baseline heart rate from pre-simulation data to identify moments of stress arousal. (3) *Debriefing and Reflection Sessions*: After each simulation, instructors facilitated debriefing sessions, guiding students to reflect on their performance. Before the next simulation, students participated in a data-based reflection session using MMLA-based feedback from the first simulation. This feedback, presented by the research team, was supplemented with comments from nursing teachers as needed to guide student reflection. These sessions were recorded and analyzed later to understand students' reactions to the feedback. A thematic analysis of these recordings was performed, identifying and categorizing significant feedback-related instances.

Figure 1

MMLA-based feedback on Stress Response of Students in ICU simulation (Sánchez et al., 2024)



Preliminary findings

The preliminary findings highlight the nuances of nursing students' reactions to multimodal feedback within a simulation-based learning environment. The reflection sessions revealed that students developed a deeper understanding and appreciation for precise, goal-oriented feedback, showing a preference for actionable feedback with clear steps for skill enhancement. The students' application of actionable multimodal feedback was noticed during the debriefing sessions. Furthermore, it was shown that multimodal feedback provides evidence that plays a dual role in reinforcing teacher observations and challenging students' self-perceptions, thereby cultivating an environment that promotes reflective practice and critical thinking.

Expected contribution

This research proposes an MMLA-based expert feedback mechanism to enhance learning in simulation settings. It seeks to deepen the understanding of learning processes through mixed methods and multimodal data analysis, with implications extending from nursing education to the intersection of learning sciences and learning analytics.

References

Blikstein, P., & Worsley, M. (2016). Multimodal Learning Analytics and Education Data Mining: Using Computational Technologies to Measure Complex Learning Tasks. *Journal of Learning Analytics*, 3(2), Article 2.

Ericsson, K. A. (2018). The Differential Influence of Experience, Practice, and Deliberate Practice on the Development of Superior Individual Performance of Experts. In A. M. Williams, A. Kozbelt, K. A. Ericsson, & R. R. Hoffman (Eds.), *The Cambridge Handbook of Expertise and Expert Performance* (2nd ed., pp. 745–769). Cambridge University Press.

McKenney, S., & Reeves, T. C. (2012). *Conducting Educational Design Research*. Taylor & Francis Group.

Pedersen, I., Lee Solevåg, A., & Solberg, M. T. (2019). Simulation-Based Training Promotes Higher Levels of Cognitive Control in Acute and Unforeseen Situations. *Clinical Simulation in Nursing*, 34, 6–15.

Sánchez, D., Kaliisa, R., Esterhazy, R., & Damsa, C. (2024). Unpacking the Elicitation Process for Multimodal Learning Analytics based Feedback. *Companion Proceedings 14th International Conference on Learning Analytics & Knowledge (LAK24)*.

Winstone, N. E., Nash, R. A., Parker, M., & Rowntree, J. (2017). Supporting Learners' Agentic Engagement With Feedback: A Systematic Review and a Taxonomy of Recipience Processes. *Educational Psychologist*, 52(1), 17–37.



Tree Climbing: Attunement to Material Contribution during Playful Climbing

Megan Goeke, University of Minnesota, goeke018@umn.edu

Abstract: Nature-based learning (NBL) approaches center nature as a “third teacher,” but how natural materials themselves shape learning is less clear. In collaboration with nature-based preschool educators, this study unpacks the mechanisms of NBL, specifically investigating how 3-5 year old children develop familiarity and patterns of engagement with natural materials such as trees and rocks through climbing. Using video recordings of children’s iterative climbing and video-cued reflections from the preschool educators, I document how variation in natural materials are noticed and responded to, both implicitly in children’s problem solving actions and explicitly in how educators scaffold the children’s engagement.

Background and goals

Imagine for a moment a group of 3-5 year old children interacting with a field of dandelions. Dandelions can be plucked, torn, twisted, scattered, arranged, and uprooted. As these children interact with the flowers, they have unique sensory experiences - the strength needed to uproot versus pluck, or the smell and feel of the inner stem. Dandelions are also embedded in cultural historical contexts, simultaneously identified as an unwelcome weed, a symbol of early spring, or salad ingredient depending on perspective. Adults and children might invoke these cultural historical perspectives, through discouraging the spread of seeds or encouraging construction of bright yellow crowns. What might we learn about learning if these ubiquitous moments of engaging with nature were centered in our educational research, treating materials as co-equal and activity contributing partners?

Nature-based learning (NBL) centers bringing nature into education - be that using natural materials in classroom experiences or hosting class outdoors - and is associated with positive benefits in terms of academic readiness, social emotional skills, overall well-being, and environmental stewardship or human responsibility for preserving nature (Kuo et al., 2019). However, the mechanisms undergirding these outcomes, both key features of NBL environments and how interpersonal dynamics contribute to unfolding engagement, are underspecified (Jordan & Chawla, 2019). Further, recent Learning Sciences research focused on Indigenous education and utilizing relational epistemology has highlighted the role adults play in initiating and reinforcing particular cultural understandings of human-nature relations (Bang & Marin, 2015), processes further shaped by experiences over time (McDaid Barry et al., 2023) and which more-than-humans are co-present in the space (Engman & Hermes, 2021). The particular NBL preschool highlighted in this study is currently in a moment of transformation, both still in the process of transitioning to a primarily NBL approach and increasing their attention to Indigenous perspectives on nature-culture relations concurrent with launching a Dakota language hub. Embracing this moment of opportunity, the NBL preschool and I initiated a partnership aimed at understanding how learning in this particular context is shaped by 1) the natural materials children iteratively interact with and 2) the explicit support given by educators around child-natural material interactions. Further, while video-based research has held interest in how physical materials are utilized in human communication, this study embraces natural materials as agentic co-participants in learning, requiring concerted adjustment to methodological practice in order to document and analyze material contributions. I specifically focused on an activity ubiquitous in this learning community - climbing with material co-participants such as trees.

Data

All data were collected in Summer 2023. First, I collected video recordings of students aged 3-5 years old engaged in both directed and spontaneous acts of climbing during a four week day camp at a local nature reserve. I was embedded in the camp for the entire period, joining students and educators every other day for a total of 8 days. Data included recording climbing with multiple synchronous cameras and general observations of learner-teacher-material interactions in field notes. In August, I conducted video-cued group interviews (Adair & Kurban, 2019) with the preschool educators, using video to elicit their thoughts regarding child-material engagement, their own actions as educators, and material agency.

Research questions and anticipated findings

How can we represent human-material engagement through transcription?



In Interaction Analysis (Jordan & Henderson, 1995), dominant transcription approaches for video data create unintended overemphasis on verbal activity, leaving relatively understudied physical actions or material context. Further, transcription is deeply influenced by theory, with theoretical lenses shaping what is made (in)visible in the transformation from raw video into written transcript. To creatively challenge the norms of transcription, I build on material agency theories from various disciplines, including design studies, posthumanism, and Indigenous perspectives, to articulate transcription procedures for material contributions to learning moments. I specifically outline theoretical distinctions between material agency theories, review how each theory has already been used in empirical video-based research, and transcribe a single video clip of preschool children and educators interacting with water to show the implications of centering each theory on the transcription process. These insights regarding transcriptions will be directly applied to the following analyses.

How do children attune over time to the contribution of natural materials within this NBL preschool's climbing activities?

This work focuses on children's iterative attempts at climbing, creating micro-longitudinal descriptions of child-material interactions and repeated climbing techniques over iterations as evidence of embodied attunement. Embodied attunement refers to sensory familiarity and the ability to sense and react to differences (Ash & Gallacher, 2015). Embracing variety of climbing co-participants, I focus on 2 hours of video-recorded interactions at two different trees and one large rock. Specifically, each child's video will be segmented based on sequences of continuous movement and pauses, allowing both tracking of child-tree/rock engagement across space and time and delineating between phases of coordinated action and deliberative problem solving.

How do educators in this NBL preschool orient attention to the contribution of natural materials?

This work addresses the need to understand how interpersonal dynamics shape NBL, particularly attending to how embodied attunement is socialized. I aim to document under what circumstances and toward what end teachers make materials explicit in learning moments, relating these interactions to larger cultural patterns of human-nature relations. Resisting methodological norms that exclude participants from sensemaking of video data (e.g. DeLiema et al., 2023), this study invites the preschool educators themselves into interpretation, first via the video-cued focus groups and second through ongoing member checking during analysis. As specialized educators who may have particular awareness of material contributions, understanding their teaching practice would provide insight into how talking about materials - not just experiencing them via our senses - shapes the embodied attunement process.

Expected contributions

Ultimately, my dissertation will provide empirical evidence concerning how materials shape children's learning, how adults scaffold children's attention to and understanding of materials, and how researchers can better represent materials in learning moments. These insights will support others in understanding and documenting the mechanisms - particularly interrelationships between natural materials as co-participants and social dynamics - undergirding NBL and other material-focused learning environments, such as makerspaces.

References

Adair, J. K., & Kurban, F. (2019). Video-Cued Ethnographic Data Collection as a Tool Toward Participant Voice. *Anthropology & Education Quarterly*, 50(3), 313–332.

Ash, J., & Gallacher, L. A. (2015). Becoming attuned: Objects, affects, and embodied methodology. In M. Perry & C. L. Medina (Eds.), *Methodologies of Embodiment* (pp. 69–85). Routledge.

Bang, M., & Marin, A. (2015). Nature-culture constructs in science learning: Human/non-human agency and intentionality. *Journal of Research in Science Teaching*, 52(4), 530–544.

DeLiema, D., Hufnagle, A., Rao, V., Baker, J., Valerie, J., & Kim, J. (2023). Methodological innovations at the intersection of video-based educational research traditions: Reflections on relevance, data selection, and phenomena of interest. *International Journal of Research & Method in Education*, 46(1), 19–36.

Engman, M., & Hermes, M. (2021). Land as Interlocutor: A Study of Ojibwe Learner Language in Interaction on and With Naturally Occurring 'Materials.' *The Modern Language Journal*, 105(S1), 86–105.

Jordan, B., & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences*, 4(1), 39–103.

Kuo, M., Barnes, M., & Jordan, C. (2019). Do Experiences With Nature Promote Learning? Converging Evidence of a Cause-and-Effect Relationship. *Frontiers in Psychology*, 10, 305



Threads of Dreaming: Cultivating Relations as a Commitment to What Could (And Should) Be in Queer and Trans Communal Clothing Making

Ali R. Blake, Boston College, ali.blake@bc.edu

Abstract: In this social design experiment I am iteratively designing, facilitating, and studying an intergenerational queer and trans communal clothing making program. QTthreads is a weekend studio program rooted in multidimensional queer and trans movements for self-determination, committed to participants' development as *historical actors*. I study historicized relation-making in program activity, joining work on expansive repertoires of historicized making practices) that attends to developing relationships as a core domain of learning. I join efforts to offer needed complexity to intertwined scholarship that attends to questions of gender(ed) justice in making environments with a needed shift from static and binary conceptualizations of gender. Specifically, I follow queer studies and trans studies scholarship to study historicized relation-making practices in fashion-ing as a site for dynamic gender self-determination and social dreaming amidst anti-queer and anti-trans hostility. I offer entry points into recognizing complexities of gendered meaning-making through arts-based, micro-ethnographic analysis adapted from Vossoughi and colleagues (2020). Methodological and empirical findings offer routes toward refusing Authoritarian efforts to extinguish queer and trans life and firmly create affirming learning ecologies that value queer and trans peoples.

Introduction and background

Clothing making, and work with textiles broadly, has seen a resurgence in education through continued investments in and status afforded to *some* making in the 'maker movement'. This movement largely remains premised on U.S. nation-bolstering, White, upper-class, largely masculine histories and visions of who makes, what they make, in what conditions, and toward what futures (Vossoughi et al., 2016). As part of addressing this narrow valuing, there is a body of scholarship attending to questions of gender(ed) equity and justice (e.g. Kafai et al., 2014; Peppler et al., 2020; Roby et al., 2023). Work with textiles is especially implicated in this scholarship, where textile making is framed as a set of disruptive (Kafai et al., 2014) feminine (Peppler et al. 2020) practices that can importantly expand the narrow valued practices of the maker movement. In the study I follow trans studies scholarship to study relation-making in fashion-ing as a site for dynamic gender self-determination and social dreaming. In so doing, I offer methods that contribute to "expanding possibilities for human expression and its interpretation" (Keenan, 2022, p. 312) in attention to gender at work in queer and trans making practices.

In efforts to recognize expansive repertoires of historicized making practices (Vossoughi et al., 2016), scholars attend to developing relationships as a core domain of learning. Relationality is one dimension of how people practice imagination toward otherwise. In this dissertation, I look to relational imagination in queer and trans communal clothing making in the program QTthreads, a social design experiment (Gutiérrez & Jurow, 2016), to join in: (i) nourishing queer and trans life amidst increasing hostility, (ii) expanding valued repertoires of making practices with attention to power in ways that don't require foregrounding Science, Technology, Engineering, and Math (STEM) learning, (iii) offering ways to attend to gender self-determination as expansive and dynamic through trans studies, and (iv) honoring ethical needs of queer and trans peoples. To do so, I ask:

RQ1: How can learning ecologies be organized around cultivating relational imagination?

RQ2: How do participants cultivate relations in QTthreads? Drawing on what histories? Toward what?

RQ3: What are participants working on through & alongside practices of communal clothing making?

Methods

This archives-animated qualitative study takes the form of a social design experiment (SDE) (Gutiérrez & Jurow, 2016) with resonant commitments from participatory design research (PDR) (Bang & Vossoughi, 2016) with a queer approach (McWilliams, 2016). A group of 20 is gathering bi-weekly for 16 three-hour sessions during the 2023-2024 academic year. Program activity is part of queer and trans social movement histories with a commitment toward program participants' development as *historical actors* (Gutiérrez & Jurow, 2016). I am following 3 focal participants, selected to illuminate heterogeneous experiences, who I join for invited visits to activities that they participate in and deem connected to their work in QTthreads.

The following forms of data generation are ongoing: fieldnotes of program sessions and design meetings; audio and/or video recordings of subgroups working together in program activity; artifacts of program design, generated in program activity, and/or in invited visits with focal participants (such as annotated sketches of garments, constructed clothing, materials for an action participants are joining, etc.); semi-structured interviews with participants (winter, and spring 2024); and analytic memos seeding analysis across forms of data.

I approach analysis with a multi-sited ethnographic sensibility across multiple scales of analysis, including the micro-ethnographic (Jordan & Henderson, 1995). In particular, I've adapted microanalytic methods from Vossoughi et al. (2020)'s study of relational histories. For analysis of RQs 1 & 2 I am refining codes for forms of *relation-making moves* and their development in interaction with fieldnotes, audio/video recordings, and interview transcripts. An initial set of forms from analysis of pilot workshops include: *stories and movements*; *offering each other openings*; *affirming playful performances*; *making what fits*; *you share a dream, I share a way*; *we need each other to bring this to life*; *bracing for hostility together*; and *reworlding from harms*. This set of moves guides selection of episodes for in-depth moment-to-moment analysis to characterize nuances that animate particular instantiations of the moves (RQ2) and the work those moves contribute to (RQ3). These analyses are supported by meaning-making in interview conversations and, when applicable, visits with focal participants. As part of these in-depth analyses I am developing a system of hand-drawn (by me) analytic drawing (Fig. 1) to highlight moments of key embodied moves and their histories within sociopolitical relations. This drawing process also offers an additional layer of anonymity, especially at a time of heightened violence toward queer and trans folks and those who join in nourishing conditions for our flourishing. Through this process I am iteratively characterizing how folks cultivate relations (RQ2), the histories those relations are participating in, and the simultaneous efforts present in activity (RQ3) in ways that foreground complexity and beauty.

Figure 1
Drawings in Process.



References

Bang, M. & Vossoughi, S. (2016) Participatory design research and educational justice: Studying learning and relations within social change making. *Cognition and Instruction*, 34(3), 173-193.

Gutiérrez, K. D. & Jurow, A. S. (2016). Social design experiments: Toward equity by design. *The Journal of the Learning Sciences*, 25(4), 565-598.

Jordan, B. & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, 4(1), 39-103.

Kafai, Y. B., Fields, D. A. & Searle, K. A. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review*, 84(4), 532-556.

Keenan, H. B. (2022). Methodology as pedagogy: Trans lives, social science, and the possibilities of education research. *Educational Researcher*, 51(5), 307-314.

McWilliams, J. (2016). Queering participatory design research. *Cognition and Instruction*, 34(3), 259-274.

Peppler, K., Keune, A., & Thompson, N. (2020). Reclaiming traditionally feminine practice and materials for STEM learning through the modern maker movement. In: N. Holbert, M. Berland, & Y. B. Kafai (Eds.) *Designing constructionist futures: The art, theory, and practice of learning designs* (pp. 127-140). MIT Press.

Roby, R. S., Calabrese Barton, A., Tan, E., & Greenberg, D. (2023). Co-making against antiBlackness. *Equity & Excellence in Education*. Online first.

Vossoughi, S., Hooper, P. K. & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review*, 86, 206-232.

Vossoughi, S., Jackson, A., Chen, S., Roldan, W. & Escudé, M. (2020). Embodied pathways and ethical trails: Studying learning in and through relational histories. *The Journal of the Learning Sciences*, 29(2), 183-223.



“To Live in the Along”: Refugee Youth Organizing and Intergenerational Learning

Sarah Priscilla Lee, Northwestern University, spl@u.northwestern.edu

Abstract: “To Live in the Along” is a 3-year ethnography of informal learning on a council with refugee youth. Using youth participatory action research (YPAR) and intergenerational learning frameworks, I examine pedagogical moments between adults and youth that support sensemaking around identity and belonging. I ask: 1) What facilitative moves support refugee youth as they make sense of their identity and belonging through the council? 2) What forms of joint work emerge to support critical consciousness? This work challenges essentialist views of refugee youth and their families and offers concrete practices for supporting acclimation through liberatory education.

Background

Building on theories of identity development and belonging, I examine out-of-school settings for refugee youth as critical sites for acclimation. Many youth simultaneously serve as cultural brokers while navigating a new language and systems. While well-meaning, OST programs are characterized by charitable benevolence and saviorism. Additionally, existing scholarship underscores the need for high-quality training in cultural competence, social emotional learning, critical pedagogies, and co-design with youth. This work expands on OST programs for refugee youth to consider organizing as a rich site for intergenerational learning that supports acclimation. Intergenerational contexts center relations between participants and shifts how knowledge is produced, who produces knowledge, and what counts as knowledge (Bang et al., 2016). This resists individualistic notions of learning and amplifies learning as a collective, political, and sociocultural endeavor rooted in relations. It democratizes and fundamentally alters normative forms of teaching and learning while uplifting pedagogies at the margin. This is consequential for narratives that refugee youth craft themselves, which critically rejects deficit stories and perpetuating colonial subjectivity (Nayeri, 2019).

Research goals

In the tension between stories that flatten refugee identities and what Sukarieh (2023) articulates as the “global youth development complex,” I focus on how refugee youth make sense of their identities and belonging on their own terms through a local youth council. The council represents a third space (Gutierrez, 2008) where refugee youth develop repertoires of practice across socio-ecological settings. Youth participatory action research (YPAR) is one way organizers pursue change at a systemic and policy level. YPAR also engenders processes of everyday learning and human development that draw on and support the existing knowledge, skills, and experience of youth. Finally, combining critical pedagogical theories and interdisciplinary methods, I hope to understand moments of intergenerational learning and facilitation that make joint work and participatory design generative. This work intervenes in the subfield of cross-cultural youth organizing, specifically with refugee youth, toward critical consciousness and liberatory education.

Methodology

This ethnographic study uses data collected and transcribed from semi-structured interviews, focus groups, field notes, analytic memos, audio and video recordings of council meetings, surveys, and artifacts (Emerson, Fretz & Shaw, 2011). I use In Vivo coding to identify themes based on phrases, stories, and noticing (Charmaz, 2003). I attend to how relationships on the council shape the conversations that emerge around identities and belonging. From these codes, I develop descriptive codes and analytic memos then organize codes into themes that emerge across the data (Miles, Huberman & Saldaña, 2014). I discuss and iterate codes with a team of youth council members and university research assistants to create a code book. The code book guides the rest of the analysis to define and log specific examples of codes.

Preliminary findings

Three emergent phenomena: First, how facilitators’ identities and training support pedagogical moves that open space for authentic engagement. Second, how youth identities surface in critical moments of joint work. Finally,



how organizational constraints impact the types of infrastructure that support co-design and facilitation across settings.

Contributions

Although situated in a local youth council, my research speaks broadly to work on youth organizing, identities, belonging, and placemaking. Studying the council as a site of intergenerational learning expands how scholars, practitioners, and organizers understand the relational *hows* of youth organizing. It aims to expand the methodological, design, and theoretical frameworks for supporting refugee youth education. This work also centers the funds of knowledge and repertoires of practice that refugee youth draw on toward critical consciousness. In the context of global refugee youth education, this work wrestles with (micro)moments of facilitation and design as youth leverage their voices and locate their collective power in spite of, and in response to, real and metaphorical boundaries and borders.

In “Speech to the Young,” Chicago poet Gwendolyn Brooks writes: “Live not for the battles won. / Live not for the end-of-the-song. / Live *in the along*.” This research honors relationships that unfold as adults and youth partner to build grassroots power and alternative futures. In other words, it embodies a commitment to the actual people and mundane processes that make social change and liberatory education possible – a commitment to living in the along.

References

Charmaz, K. (2008). Grounded Theory as an Emergent Method. In S. N. Hesse-Biber & P. Leavy (Eds), *Handbook of Emergent Methods* (pp. 155-172). New York: The Guilford Press.

Emerson, R. M., Fretz, R. I., & Shaw, L. L. (2011). Writing ethnographic fieldnotes. University of Chicago Press.

Gutiérrez, K. D. (2008). Developing a Sociocritical Literacy in the Third Space. *Reading Research Quarterly*, 43(2), 148–164. <https://doi.org/10.1598/RRQ.43.2.3>

Miles, M.B., Huberman, A.M. and Saldana, J. (2014) Qualitative Data Analysis A Methods Sourcebook. Sage, London.

Nayeri, D. (2019). The ungrateful refugee: what immigrants never tell you. New York, NY, Catapult.

Sukarieh, M. (2023). A Global Idea: Youth, City Networks, and the Struggle for the Arab World. Cornell University Press; JSTOR. <http://www.jstor.org.turing.library.northwestern.edu/stable/10.7591/j.ctv2zmkb7v>



Imagination and Action in Mathematical Reasoning and Transfer

Fangli Xia, University of Wisconsin – Madison, fxia24@wisc.edu
Mitchell J. Nathan, University of Wisconsin – Madison, mnathan@wisc.edu

Abstract: The dissertation investigates how *action prediction* – prompting students to *imagine* (i.e., *simulate*) outcomes of task-relevant actions on imagined mathematical objects – influences complex reasoning and knowledge transfer in advanced mathematics. The proposed studies use experimental designs with an interactive, embodied video game to elicit embodied actions and collect multimodal data. Quantitative and qualitative analyses of multimodal data will explore malleable factors (e.g., action and self-explanation), mediators (e.g., gesture), and moderators (e.g., student characteristics) associated with imagination and action that may benefit mathematical reasoning and learning.

Introduction

Mathematical formalisms, such as symbols and notations, are fundamental in STEM, but often challenge learners due to their arbitrary and abstract nature. Grounded and embodied mathematical cognition posits that learners' thinking and learning rely on body-based processes to become meaningful. Mathematical ideas can be activated by performing task-relevant physical movements, even when these movements are only imagined. Previous research has shown that directing students to perform task-relevant actions (i.e., directed actions) contributes to nonverbal processes such as mathematical insight (e.g., Nathan & Walkington, 2017).

Still, several themes can be further explored. First, while directing learners to perform actions that are *externally generated* by researchers enhances mathematical thinking, prompting them to imagine or perform their own actions that are *self-generated* can make the learning more personal and potent (Abrahamson & Sánchez-García, 2016). Second, explicitly connecting one's actions to tasks may further engage conceptual reasoning (Nathan & Walkington, 2017). Third, embodied interventions rely on concrete movements and perceptions rather than symbolic abstractions to convey information, raising questions about their effectiveness for forming generalizations and knowledge transfer. My dissertation addresses these issues by investigating how imagining task-relevant actions, coupled with language that explicitly explains the connection between actions and tasks, impacts mathematical thinking and transfer.

My dissertation takes a novel approach called *action prediction* to elicit students' imaginations of their *self-generated* actions. This approach prompts students to predict (i.e., mentally *simulate*) task-relevant actions that enact properties and transformations of imagined mathematical objects. This intervention leverages the affordances of motor control, a system that anticipates plausible outcomes of planned actions by generating feedforward (predictive) signals and monitoring their impact on the world (feedback). In a mathematical context, prompting students to anticipate the plausible outcomes of the transformations they simulate performing on imagined mathematical objects can induce reasoning and inference, even for complex geometric concepts (Nathan & Walkington, 2017). Thus, I hypothesize that by connecting the anticipatory nature of the action with reasoning processes, action prediction can foster embodied reasoning and support generalization and transfer.

My dissertation investigates this hypothesis in the task domains of secondary geometric proof and mathematical function, two topics that are essential for promoting future studies and work in STEM fields. The research is guided by three interrelated goals: (1) examining the cognitive influence of action and action predictions on mathematical reasoning; (2) unpacking the potential contribution of multimodal self-explanations that emerges from participants' embodied reasoning; and (3) exploring the impact of the sources of actions (self-generated action predictions versus externally generated directed actions) on the transfer of embodied knowledge.

Methods, preliminary and expected findings

My dissertation comprises three studies. Study 0 (pilot) used a 2x2 between-subjects design to investigate whether and how making action predictions (AP) or directed actions (DA), individually, together, or neither (control) influence undergraduates' (N=127) geometric reasoning. Each participant then evaluated and verbally justified eight geometric conjectures (e.g., *The diagonals of a rectangle always have the same length*). Multimodal data, including verbal responses, gestures, surveys about participants' characteristics (e.g., spatial ability), were collected for qualitative and quantitative analysis. Preliminary results show that prompting students to make action predictions led to enhanced proof production. Furthermore, when either DA or AP were re-enacted in learners' explanations as *gestural replays*, both DA and AP led to improved proof production. Notably, participants who made only AP outperformed those who performed only DA (Xia et al., 2023). Study 0 provides strong evidence



that action predictions foster embodied mental simulations of mathematical transformations, as revealed by participants' *gestural replays* that re-enact their earlier actions, benefit mathematical reasoning, laying the basis for Studies 1 and 2.

Study 1 expands on Study 0 by examining the potential role of *multimodal (gestural and verbal) self-explanations* that participants produced to connect actions and math tasks while engaged in AP. Study 1 uses a 2x2 between- and within-subjects design to investigate whether prompting self-explanations when performing DA or AP enhances geometric reasoning more than performing actions alone. It will use a motion-capture video game, *The Hidden Village-Online* (THV-O), to elicit both DA and AP for geometry tasks. THV-O can detect participants' body movement in real time. Students (N = 88; based on power analysis) will be randomly assigned to either AP or DA. Within each condition, participants will be prompted to use both speech and gesture to self-explain how the actions they imagine or physically perform connect to each conjecture for half of the tasks, as they will evaluate and verbally justify six conjectures. Data will include participants' speech, gestures, surveys about participants' characteristics for qualitative and quantitative analyses. For the results, I expect that students who are prompted to generate multimodal self-explanations will be more likely to generate correct mathematical insights and valid proofs. This is likely because self-explanations can integrate task-relevant unconscious processes, such as perception, and conscious processes, such as logical thinking, in the service of mathematical reasoning. As in Study 0, I also expect AP to outperform DA because imagined actions engage both feedforward and feedback processes that foster mental simulation of mathematical operations that help conceptualize general geometry properties.

Study 2 extends the investigation to explore whether and how embodied interventions (AP or DA), along with multimodal self-explanations, contribute to knowledge transfer in the domain of mathematical functions. This study continues to use THV-O to elicit DA and AP for function tasks. The study uses a 2x2 between- and within-subjects (N = 120) pre-post experimental design that includes near and far transfer items. Building on previous studies, I will quantitatively model how these conditions affect task performance and qualitatively analyze how participants use *gestural replays* during their reasoning and across near and far transfer tasks. I expect to see superior transfer for trials where participants are prompted to perform actions and make multimodal self-explanations, and that these will be rich with *gestural replays* of earlier actions. Furthermore, this study will reveal whether multimodal explanations for *self-generated* AP are likely to lead to more gestural replays and superior proof performance on tasks compared to DA. Gestures can *schematize* key invariant relations, thus facilitating generalization and transfer beyond the concrete actions. These expectations are grounded in the *embodied theory of transfer*, which posits that embodied experiences facilitate transfer by reenacting modes of perception and action in new contexts (Nathan & Alibali, 2021).

Expected contributions

This work introduces a novel approach to improve students' mathematical reasoning, learning, and transfer by prompting them to predict and simulate performing movements for mathematical objects. It extends theory and practice in embodied cognition, mathematics education, and educational technology in several ways. First, it is one of the very few studies that uses various randomized controlled experimental designs to explore the role of action predictions on cognition across mathematics domains. Second, it can reveal how multimodal (gestural and verbal) self-explanations help bring unconscious, action-based understanding to consciousness. Third, it stands to contribute to the embodied theory of transfer by revealing how learning that arises during embodied interventions generalizes to new contexts. Fourth, it examines how the source of movements (i.e., externally directed versus self-generated) affects mathematical thinking and transfer. Finally, this study introduces an interactive video game that allows delivery and creation of action-based interventions, positioning this work for future scale-up implementations.

References

Abrahamson, D., & Sánchez-García, R. (2016). Learning is moving in new ways: The ecological dynamics of mathematics education. *Journal of the Learning Sciences*, 25(2), 203-239.

Nathan, M. J., & Alibali, M. W. (2021). An embodied theory of transfer of mathematical learning. *Transfer of learning: Progressive perspectives for mathematics education and related fields*, 27-58.

Nathan, M. J., & Walkington, C. (2017). Grounded and embodied mathematical cognition: Promoting mathematical insight and proof using action and language. *Cognitive research: principles and implications*, 2, 1-20.

Xia, F., Swart, M. I., Schenck, K. E., & Nathan, M. J. (2023). Gestural Replays Support Mathematical Reasoning by Simulating Geometric Transformations. In *Proceedings of the 17th International Conference of the Learning Sciences-ICLS 2023*, pp. 305-312. International Society of the Learning Sciences.



Materials-To-Queer-With: Weaving a Queering of Undergraduate Mathematics

Nickolina Yankova, University of California, Irvine, nyankova@uci.edu

Abstract: This dissertation is a qualitative study, drawing on principles of design-based research, constructionism, and queer theory, toward the design of an undergraduate class, which disrupts normative practices in mathematics with new tools and materials. Informing my design are interviews with queer students while video and artifact data analysis from the course uncover new ways of engaging in the “doing of” mathematics. Implications promise to advance theoretical and design contributions for a “queering” of mathematics.

Introduction and background

With the queer turn in mathematics education (Dubbs, 2016) and the present political landscape, now more than ever there is an urgency to go beyond advocating for inclusion and representation and “queer” or subvert normative learning practices in mathematics, a discipline canonically presumed to be bias-free yet still steeped in social context. Though historically feminized and occupying a tension-filled space, straddling domesticity and innovation, fiber crafts present an opportune context to begin such explorations. Fiber crafts have supported instantiations of activism and given rise to advancements within math and computer science including the Jacquard loom, which inspired the modern computer (e.g., Essinger, 2004). Though work has been done around gender and critical feminist perspectives regarding craft and math learning (e.g., Thompson, 2020), queer theory would theorize craft as more than a space for women but as a queer space that can productively disrupt old norms and practices with new tools and materials. This dissertation contributes to a pressing call for new models of queering mathematics curriculum and content and following how it unfolds in practice (Dubbs, 2016), as I lean on principles from design-based research (e.g., Brown, 1992) and constructionist learning theory (Papert, 1980) at its intersection with queer theory (e.g., Sumara & Davis, 1999) to design for and study student learning in an interdisciplinary undergraduate class conceived as a queering of mathematics.

Textiles are a provocative context to situate a queering of mathematics with their inherent mathematical properties crafting tangible evidence of math learning. Drawing on queer perspectives within the learning sciences has not been very common, yet queer theory has much to offer learning scientists, especially those interested in the design of more equitable learning environments for queer students (McWilliams & Penuel, 2016). On the other hand, with its focus on design and artifact production, on process over product, and on making sense of failure, constructionism (Papert, 1980) finds synergy with queer theory, with queer theory perspectives adding a critical lens to constructionism, crafting a space to productively tackle an exploration of *materials-to-queer-with*. In this dissertation, I build on prior work exploring the potential of fiber crafts (e.g., knitting, crochet, weaving) to transform current mathematics learning practices (e.g., Thompson, 2020) and extend it through a queer theory lens. I ground my work in our current project, which uses weaving as a context for learning computational practices. Nevertheless, at its roots, weaving is a site for advanced learning in mathematics (e.g., weaving drafts can be represented as a product of binary matrices). This project has provided me with the needed materials (i.e., Robo-Loom, a robotic Jacquard loom aimed for educational contexts and suited for mathematics explorations) to situate and explore a queering of mathematics and the learning that transpired.

Methodology

Informing my design were interviews with queer students, which helped me better understand the queer experience in mathematics and the interplay of factors that characterize math as a white, male dominated space, positioning whiteness and masculinity as the norm, to be disrupted (Yankova, 2024). Context for the second part of my dissertation was a 10-week elective undergraduate class in Informatics at the intersection of mathematics, robotics, and textile arts ($n = 23$). The course built on and extended an earlier version of the course, piloted at our partner institution. Students worked in groups to design and weave their textiles with Robo-Loom, drawing on math principles. Throughout the course, I collected video and artifact data, as well as survey, reflection, and assessment data, toward understanding student learning and the strengths and limitations of the design. As part of my analysis, I will use video data analysis and artifact analysis to shed light on how students engaged in the “doing of” mathematics as part of textile production and in their interactions with Robo-Loom and each other. I will thematically analyze student reflections for design components that were successful and those that need iteration.



Analysis and emergent findings

Interview findings point to the following emergent themes as points of disruption toward more equitable practices in mathematics, essentially constituting design goals to aim for: *reinforcing the binary; reinforcing neutrality; math as fixed; math as gendered* (Yankova, 2024). Designing to disrupt these four practices and foster an environment that embraces intersectional identities, I aimed to integrate the following in the course design: *challenging the dominant tools and materials, embracing failure as an outcome, leveraging mathematics in applied contexts and collaboration, and design of personally meaningful artifacts*.

To understand student learning, I use video data analysis (Goldman et al., 2014) toward inductively deriving emergent themes, homing in on the moments in which mathematics understanding emerges as students interact with Robo-Loom and each other. I further use a case study approach of one group which explored Jacquard weaving and more complex weaving patterns, creating the longest textile project, which will provide me the opportunity to investigate their process and design development over time, and ultimately, learning over time. The group further had moments dense in talk related to crafting (weaving) practices and math practices, giving rise to a preliminary coding scheme: Design talk (e.g., *color, pattern, cloth properties*); Math talk (e.g., *binary representation, dimensionality, symmetry*); Engagement with Robo-Loom (e.g., *calibration, weaving, debugging*); Role distribution.

Preliminary findings highlight Robo-Loom as an anchor to point to and to use to contextualize designs and woven artifacts (e.g., referencing Robo-Loom and number of motors to figure out the design dimensions). Additionally, in observing emergent cloth properties (e.g., falling apart or unraveling at the edges) students tended to flow between what's material to the mathematical representation and vice versa, with the tangible engagement informing their design decisions and changes to the pattern. Considerations of yarn color, on the other hand, tended to prompt discussion for what should be encoded with 0s and what with 1s in the design, disrupting the binary notation of weaving patterns, with color imbuing meaning to 0s and 1s. Patterns in weaving design further offered opportunity for mathematical engagement with the notion of symmetry (e.g., symbol repetition as an example of translational symmetry affording a crossover between design and math talk).

Expected contributions

I anticipate this dissertation will advance theoretical and design contributions across three axes. First, extending our previous work, I focus explicitly on queering the tools and materials in mathematics through weaving, what has largely been underexplored in extant efforts toward queering mathematics. Second, by bridging constructionism with queer theory, I hope to advance design applications of queer theory within the learning sciences. Lastly, I extend our previous work and knowledge around crafting and learning mathematics with queer theory, dismantling previous binary divides around simplicity as explained by gender, for instance, and helping make sense of unfolding complexity.

References

Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of Learning Sciences*, 2(2), 141–178.

Dubbs, C. (2016). A Queer Turn in Mathematics Education Research: Centering the Experience of Marginalized Queer Students. North American Chapter of the International Group for the Psychology of Mathematics Education.

Essinger, J. (2004). *Jacquard's web: How a hand-loom led to the birth of the information age*. Cambridge, UK: Oxford University Press.

Goldman, R., Pea, R., Barron, B., & Derry, S. J. (Eds.). (2014). *Video research in the learning sciences*. Routledge.

McWilliams, J., & Penuel, W. R. (2016). Queer theory in the learning sciences. In *Power and Privilege in the Learning Sciences* (pp. 111-132). Routledge.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.

Sumara, D., & Davis, B. (1999). Interrupting heteronormativity: Toward a queer curriculum theory. *Curriculum Inquiry*, 29(2), 191-208.

Thompson, N. (2020). *Weaving Together: Exploring How Pluralistic Mathematical Practices Emerge Through Weaving* (Doctoral dissertation, Indiana University).

Yankova, N. (2024). Math in the Messy: Breaking Down Norms “Queer”-ly. In *Learning as a corner-stone of healing, resilience, and community: ISLS Proceedings: 17th Annual Conference of the Learning Sciences*. Buffalo, New York: International Society of the Learning Sciences.

Exploring Motivational Beliefs in Middle School Makerspaces: Analysis of Socio-cognitive Influences, Material Interactions, and Gender Dynamics

Nisumba Soodhani K, Indian Institute of Technology Bombay, India, nisumba_soodhani@iitb.ac.in

Abstract: This research delves into the motivational beliefs of middle school students engaged in makerspace activities to uncover factors driving participation and those presenting obstacles. Employing a socio-cognitive framework, the study explores motivation and self-efficacy through the lens of self, behaviour and environment. We employ a new methodology by using interaction analysis to get a comprehensive idea of the self-efficacy and motivation of learners in makerspaces. To get a more nuanced understanding of the interplay of self-efficacy and gender, the pilot study's video data was analysed using interaction analysis and triangulated with self-report surveys and interviews. Preliminary findings reveal insights into how self-efficacy develops, as learners are involved in mastery experience and how material preferences shape their involvement in making activities. The ongoing study involves ethnography comprising videos, photos, field notes and interviews. The research is aimed at contributing to the existing literature on motivation and makerspaces and understanding the gender dynamics from the socio-cognitive perspective in the context of Indian middle school learners.

Goals and background

The primary goal of my research is to gain insights into the motivational beliefs of middle school learners actively participating in makerspace-related activities. The research strives to identify the factors driving their participation and those posing obstacles. The significance of this research becomes apparent when we consider the existing gaps in understanding the motivational beliefs of makers. The motivational dynamics, particularly in the demographic of middle school learners, still need to be more adequately explored (Lin et al., 2020). Moreover, research in makerspaces has identified a noticeable gender disparity in participation, pointing to self-efficacy being an influencing factor (Andrews et al., 2021). More often self-efficacy has been studied using cross-sectional analysis or longitudinal analysis using surveys. Static self-efficacy assessments track pretest-to-posttest changes but miss fine-grained changes during task engagement (Schunk, & DiBenedetto, 2021). To understand the existing inequalities in makerspaces, and why and how they are linked to self-efficacy, a more situated approach to analysing it is needed. Consequently, an in-depth understanding of motivation and related constructs is essential to address the gender disparity in makerspace engagement.

To better comprehend the dynamics of makerspaces, motivation and gender, we delineate four layers of influence. The first layer involves the cultural values and expectations that may prescribe gender roles and the influence it has on learners' motivations and behaviours in makerspaces. The second layer delves into the subculture of makerspaces, exploring the aspirations of makers and the types of making valued within these environments. The third layer focuses on the exploration of maker-material interaction which includes the materials and their associated histories which can significantly impact how learners perceive the makerspace (Keune, 2022). Lastly, the fourth layer revolves around personal beliefs that influence the motivation of individuals. In this context, we consider self-efficacy, task value, outcome expectation, interest, and goal orientation which can influence motivational beliefs (Panadero, 2017). Among the existing theories focusing on motivation, Socio-Cognitive Theory (SCT) takes into consideration the influence of the individual, their beliefs, and the environment (Bandura, 1999). It also speaks about the triadic reciprocal causation effect all these three have on each other, hence we adopt this theory for our research. This thesis primarily operates in layer 4, with the second and third layers setting the context of research. This study focuses on government school-maker activities in India which cater to students from economically disadvantaged backgrounds. The making activities focus on physical and creative computing. The predominant questions driving the study are:

RQ 1: What primary motivational factors prompt active participation among middle school learners in makerspace activities?

RQ 2: How do socio-cognitive influences and gender dynamics intersect within makerspace environments?

RQ 3: How does self-efficacy vary during making activities, and what are the factors influencing these variations?

Methodology

A preliminary pilot study was conducted in a controlled environment centred around self-efficacy, a key motivational construct (Bandura, 1993). We used diverse data sources, including (1) video data, (2) interviews, and (3) self-report - MSLQ: Motivated Strategies for Learning Questionnaire (Pintrich, 1991). In this study, eleven learners of age 12 to 15 participated. To analyse the data, we employed 'interaction analysis' as an analytical approach, complemented by self-report surveys and interview data (Jordan & Henderson, 1995). This analysis approach provided valuable insights like, self-efficacy is not solely influenced by general perceptions but is distinctly shaped by specific struggles and preferences related to materials within the makerspace. Building on this study, to know more about how and why self-efficacy is changing and what factors majorly influence the self-efficacy of learners the ongoing longitudinal data collection focuses on observing participants in their natural environment - school-based makerspaces. Adopting ethnography as a method, the researcher actively participates in the daily life of the makerspace, capturing the socially distributed cognitive practices and interactions with the environment. This involves the collection of digital video recordings, field notes, interviews, and other available data to shed light on the focal points of the research. Interviews of facilitators and learners will be analyzed followed by analysis of video data. Interaction analysis will be used and results from interviews will be triangulated to comment on various layers through which motivational factors influence the active participation in makerspaces.

Analysis and emerging findings

The preliminary findings from the pilot study include the identification of behavioural indexes of self-efficacy in episodes like - self-affirming gestures, taking videos of artifacts, identifying the potential of familiar materials and utilizing it, and avoiding a material because of prior struggles. This further raises questions about how Layer 3 and Layer 4 are affected by each other. Additionally, an interesting gender-based observation emerged—the type of artifact created was more craft-oriented when girls performed the tasks, whereas boys tended to produce artifacts focused on functional problem-solving. Though it seems to propagate the idea of gender stereotypes in makerspaces literature, a more detailed analysis is required to get a clear picture of what motivated them to create these artifacts. Beyond self-efficacy, the ongoing research explores the interplay of various sub-constructs of motivation, such as task value, outcome expectation, interest, and goal orientation. We anticipate uncovering factors contributing to participation in makerspaces with a focus on motivational belief and self-efficacy.

Expected contribution

The anticipated contributions from this thesis are multi-faceted. Firstly, it seeks to enrich the existing motivation in makerspace literature by offering a nuanced exploration of various motivational constructs. Secondly, the research introduces interaction analysis in conjunction with traditional methods like self-report surveys and interviewing which respond to the call for tracking fine-grained changes in how motivation varies in the course of learning. This is also possibly the first few studies exploring making activities in the context of Indian government schools. By delving into the analysis of different layers, this research aims to contribute valuable insights that can inform interventions to improve participation, especially among girls.

References

Andrews, M. E., Borrego, M., & Boklage, A. (2021). Self-efficacy and belonging: The impact of a university makerspace. *International Journal of STEM Education*, 8, 1-18.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational psychologist*, 28(2), 117-148.

Bandura, A. (1999). Social cognitive theory of personality. *Handbook of personality*, 2, 154-96.

Bandura, A., Freeman, W. H., & Lightsey, R. (1999). Self-efficacy: The exercise of control

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, 4(1), 39-103.

Keune, A. (2022). Advancing the materiality of gender equitable STEM learning. In *International Collaboration toward Educational Innovation for All* (pp. 135-136).

Lin, Q., Yin, Y., Tang, X., Hadad, R., & Zhai, X. (2020). Assessing learning in technology-rich maker activities: A systematic review of empirical research. *Computers & Education*, 157, 103944

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in Psychology*, 8, 422.

Schunk, D. H., & DiBenedetto, M. K. (2021). Self-efficacy and human motivation. In *Advances in motivation science* (Vol. 8, pp. 153-179). Elsevier.



Enhancing Teacher Reflection and Feedback on Classroom Discourse During Video-Based Professional Development: A Visualization Approach

Chao Yang, The University of Hong Kong, chaoyang@connect.hku.hk
Gaowei Chen, The University of Hong Kong, gwchen@hku.hk

Abstract: This study investigates the design and implementation of a visualization approach to facilitate teacher reflection and feedback on their classroom discourse. A between-subjects study will be conducted in a year-long hybrid video-based teacher PD program. We plan to recruit 60 mathematics teachers from 12 secondary schools, and they will be divided into one intervention group and two comparison groups. Both quantitative and qualitative data will be collected to validate the effectiveness of the visualization approach in aligning teachers' reflection, feedback, and enactment of dialogic teaching practice.

Introduction and background

Teachers' orchestration of classroom dialogue is important in fostering student thinking and learning development (Kim & Wilkinson, 2019). From Vygotsky's (1978) sociocultural theory, classroom discourse provides a constructive context for classroom interactions. Studies found that engaging in reflective practice toward classroom discourse offers significant insights for teachers to enhance their instructional effectiveness as well as improve student learning outcomes (Chen et al., 2020; Walsh, 2013). One effective approach to promote this reflective process is through videos, which serve as a powerful tool for teachers to observe and reflect on classroom dialogue. Video-based reflection enables teachers to deepen their understanding of classroom interactions, prompt critical reflection, and facilitate the exchange of peer feedback (Borko et al., 2008; Kleinknecht & Gröschner, 2016). However, teachers may be overwhelmed by excessive information in video viewing, and struggle to track their learning and changes in teaching during PD programs. Moreover, they tend to reflect in an isolated way, which hinders the opportunity to collaborate with their peers. Visualization technologies hold the potential to address these challenges. Scholars have employed visual learning analytics (VLA, Vieira et al., 2018) which utilizes visualizations to represent educational datasets to carry out learning analytical tasks efficiently. In this study, we aim to design a visualization approach to facilitate teacher reflection and feedback on classroom discourse, and validate the effectiveness of the approach through a between-subjects study in a year-long hybrid video-based teacher PD program.

Methodology

Study design

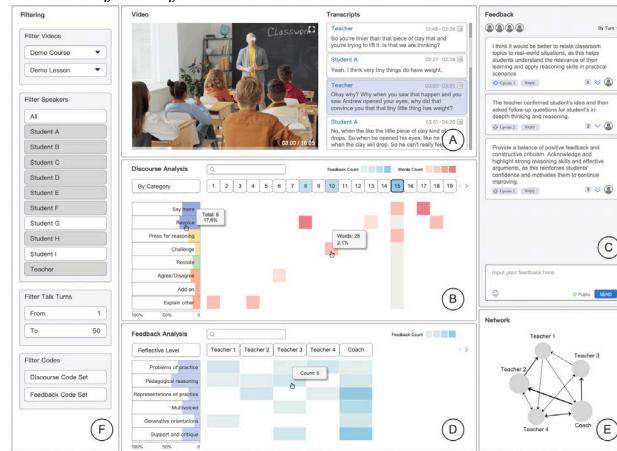
A total of 60 mathematics teachers, including 48 novice teachers and 12 coach teachers across 12 secondary schools will be enrolled in the study. They will be divided into 12 sub-groups, each comprising four novice teachers and one coach teacher. Four groups are to be assigned to an intervention condition to reflect on their lesson videos and share their reflective feedback with peers using the TRFlens in a hybrid PD mode, four groups to the first comparison condition to perform a similar PD mode using a baseline system without visualization support, and the other four groups to the second comparison condition to perform a conventional PD mode. There are six PD cycles in the hybrid PD model, each comprising an online session for teachers to reflect on their lesson videos with TRFlens and provide feedback to each other asynchronously, and a face-to-face session, in which teachers will gather in a classroom and be guided through a set of reflective tasks and discussions on their dialogic teaching practice with the aid of TRFlens.

Multiple sources of data including classroom video recordings, classroom discourse, teacher feedback, usability test questionnaires, teacher interviews, workshop discussions, reflective journals, and pre-and post-tests on teachers' self-efficacy in orchestrating classroom talk will be collected for both quantitative and qualitative analysis to address the following research questions: RQ1. Are there any differences in depth of reflection between the intervention and comparison groups? RQ2. To what extent are the different features of reflective feedback associated with improved teacher classroom talk over time? RQ3. How do the intervention teachers regard the visualization approach as an effective tool for reflection and feedback?

Visualization system design

Teacher Reflection and Feedback Lens (TRFlens) is a visual learning analytical tool that utilizes visualization and AI technologies to accurately capture, classify, and visualize classroom talk and peer feedback based on classroom videos (Figure 1). It visualizes the classroom talk and tracks how teachers' peer feedback was generated across talk turns to facilitate teachers' reflection and the quality of classroom talk in teaching practice. We use timeline-based heatmaps to help teachers navigate through context information of talk moves and peer feedback associated with video and transcripts (Figure 1_B, D), and network maps to visualize group structure and interactions among group members (Figure 1_E). We adopt the framework of academically productive talk (APT, Resnick et al., 2015) and pedagogically productive talk (PPT, Lefstein et al., 2020) to classify classroom discourse and teacher feedback datasets automatically by the power of large language models (LLMs, i.e., GPT-4).

Figure 1
The Interface of TRFlens



Expected contributions

This study shall contribute to the field of computer-supported collaborative learning and teacher PD from three aspects. Theoretically, this study strives to provide empirical knowledge on how technological advances can support teachers' reflective process of classroom teaching. Methodologically, the integration of visualization technologies into video-based reflection represents a novel approach to teacher PD design. Practically, it could offer implications for the design considerations of both face-to-face and online teacher learning environments.

References

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, 24(2), 417-436.

Chen, G., Chan, C. K., Chan, K. K., Clarke, S. N., & Resnick, L. B. (2020). Efficacy of video-based teacher professional development for increasing classroom discourse and student learning. *Journal of the Learning Sciences*, 29(4-5), 642-680.

Kim, M. Y., & Wilkinson, I. A. (2019). What is dialogic teaching? Constructing, deconstructing, and reconstructing a pedagogy of classroom talk. *Learning, Culture and Social Interaction*, 21, 70-86.

Kleinknecht, M., & Gröschner, A. (2016). Fostering preservice teachers' noticing with structured video feedback: Results of an online-and video-based intervention study. *Teaching and Teacher Education*, 59, 45-56.

Lefstein, A., Vedder-Weiss, D., & Segal, A. (2020). Relocating research on teacher learning: Toward pedagogically productive talk. *Educational Researcher*, 49(5), 360-368.

Resnick, L. B., Austerhan, C., & Clarke, S. N. (Eds.). (2015). *Socializing intelligence through academic talk and dialogue*. American Educational Research Association.

Vieira, C., Parsons, P., & Byrd, V. (2018). Visual learning analytics of educational data: A systematic literature review and research agenda. *Computers & Education*, 122, 119-135.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Walsh, S. (2013). *Classroom discourse and teacher development*. Edinburgh University Press.

Acknowledgments

This work was supported by Hong Kong RGC, University Grants Committee (Grant No.: 17605221).



Author Index

A. Susan Jurow, 3, 92
Abhijit Kapre, 81
Aditi Wagh, 21
Ahmad Khanlari, 99
Akshay Kedari, 81
Ali R. Blake, 151
Amanda Provost, 3
Amber Simpson, 56
Anastasia Sanchez, 69
Annelies Raes, 107
Arnan Sipitakiat, 103
Ashok Goel, 62
Barbara J. Natalizio, 60
Beatriz Salazar, 89
Ben Kirshner, 89
Benedetta Piantella, 29
Bodong Chen, 34, 99, 107
Boris Steipe, 99
Bradford Mott, 7
C. Naomie Williams, 95
Carl Bereiter, 99
Carol K. K. Chan, 99, 107
Carolyn D. Sealfon, 60
Chad Dorsey, 85
Chao Yang, 11, 161
Chen Feng, 7
Cheolil Lim, 17
Chew Lee Teo, 99
Chris Jadallah, 69
Christopher Hoadley, 81
Cindy E. Hmelo-Silver, 7
Colin Hennessy Elliott, 56
Daeun Hong, 7
Dan Roy, 21
Daniel Hickey, 66
Daniel Sánchez, 147
Daniel Wendell, 21
David DeLiema, 56
David Dobervich, 46
David Perl-Nussbaum, 143
Deborah Dutta, 73
Devayani Tirthali, 81
Dina Solomon, 99
Dor Abrahamson, 14
Elizabeth Mendoza, 89, 92
Erin Riesland, 26
Fangli Xia, 155
Fernando Castillo, 99
Freydis Vogel, 66
Gaowei Chen, 11, 161
Gaoxia Zhu, 99
H. Chad Lane, 62
Haiyi Zhu Carnegie Mellon University, 95
Hong Shui, 34
Ilona Ilowiecka-Tańska, 14
Isabel Sieh, 46
Ishan Joshi, 34
James D. Slotta, 81
James Lester, 7, 62
Jason Corwin, 7
Jennifer Kahn, 42
Jeremy Roschelle, 62
Jessica Fernández, 89
Jessica Blake-West, 23
Jianwei Zhang, 99
Jillian Hanesworth, 6
Jinjun Xiong, 62
Joey Huang, 129
Jonathan Pang, 103
Jonathan Rowe, 62
Jooeun Shim, 113
Jou-Yin Chen, 135
Jun Oshima, 107
Juno Hwang, 17
Kaleb Germinaro, 69
Katarzyna Pomian Bogdanov, 145
Katarzyna Potega vel Żabik, 14
Katharina M. Bach, 77
Katherine M. Miller, 85
Katie Headrick Taylor, 26
Kelli Paul, 7
Kelsie Fowler, 69
Kevin Palzer, 141
Kimberly Farnsworth, 7
Krista Cortes, 92
Krista Glazewski, 7
Leah F. Rosenbaum, 103
Lex Hunter, 89
Linda Massey, 99
Lisa Hardy, 42
Luis Morales-Navarro, 56
Lydia Cao, 99
Maleka Donaldson, 56
Manoli Pifarré, 5
Marcela Borge, 66
Margaret Ellen Seehorn, 95
Marijke Hecht, 69
Marina Bers, 23
Marisa A. Holzapfel, 60
Marlene Scardamalia, 99
Megan Goeke, 149
Megan Humburg, 127
Megan Selbach-Allen, 46
Mei-Hwa Chen, 99
Mia Ellis-Einhorn, 95
Michelle Lui, 107
Mitchell J. Nathan, 155
Monica Resendes, 99



Nancy Price, 69
Nichole Pinkard, 5
Nickolina Yankova, 157
Nicole Panorkou, 3
Nisumba Soodhani K, 159
Omid Noroozi, 107
Parastoo Alikhani, 31
Paulo Blikstein, 38, 81, 103
Peeranut Pongpakati, 103
Peter Foltz, 62
Peter Wardrip, 52
Phi Nguyen, 115
Philip Bell, 69
Pooya Sabeti, 31
Preeti Raman, 81, 99
Qiuyan Wu, 137
Raquell M. Holmes, 60
Rashida Govan, 89
Renato Carvalho, 81
Rishi Krishnamoorthy, 119
Rogers Kaliisa, 121
Rotem Israel-Fishelson, 125
Sameer Honwad, 81
Samuel Abramovich, 52
Sarah Bichler, 77
Sarah Priscilla Lee, 153
Sarah Radke, 42
Seung Lee, 7
Shakuntala Gopal, 81
Sharleen Loh, 21
Shuqin Li, 139
Solicia Lopez, 89
Stacy Costa, 99
Sumin Hong, 17
Suraj Uttamchandani, 73
Syeda Anjum, 29
Taeyeon Eom, 17
Tanmay Sinha, 117
Thérèse Laferrière, 99
Tianshu Wang, 7
Tugce Aldemir, 131
Valentina Nachtigall, 123
Victoria Delaney, 46
Vincent Aleven, 95
Walter Akio Goya, 103
Wenli Chen, 4, 107
Wenxi Chen, 34
Xiaotian Zou, 7
Xinran Zhu, 34
Yeshi Paljor, 81
Yipu Zheng, 38
Yuqin Yang, 99
Zarek Drozda, 85