The Design and Implementation of a Method for Evaluating and Building Research Practice Partnerships

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ABSTRACT

We have established a research-practice partnership (RPP) to build a computer science (CS) and computational thinking (CT)-focused STEM ecosystem at two middle schools. Creating such an ecosystem to broaden student participation in computing through an RPP approach involves all stakeholders in the research process. Borrowing upon visual participatory research methods, we developed a graphic research instrument to engage teachers in the research process and elicit their perspectives on strategies for building the ecosystem. This experience report describes our research methodology across two distinct cases to demonstrate the utility of this drawing activity as an investigative and partnership development tool. The contribution is in offering a flexible approach to other university-based RPP teams that enables a synergistic partnership development tool and data collection instrument that can be tailored to a variety of RPP contexts, facilitating more productive and equitable ways of engaging stakeholders in the research process. We describe our project contexts and share results from the pilot study with practitioner-members of our RPP teams. We discuss two cases to highlight the contribution this approach made to the development of our partnerships.

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1 Introduction

Despite growing demands for computationally-intensive STEM professions, many groups (e.g., women, Black, Hispanic/Latinx) continue to be marginalized from this important work [2]. Disparities in workforce participation are reflective of a systemic problem where these individuals often lack access to early opportunities to engage in and develop an interest in computer science (CS) and computational thinking (CT) practices [10]. In order to address this critical need, our university-based teams have developed a research-practice partnership (RPP)–an intentional, long-standing, and equitable collaboration between researchers and teachers–at two different middle schools in order to establish a CT/CS-focused ecosystem model at each school. Moreover, our application of the ecosystem model recognizes that effective CS/CT learning is the product of the entire connected academic enterprise. Elements of this connected enterprise include school leadership, teachers, available CS/CT resources and learning opportunities, along with prior experiences, encouragement, and training in CS/CT [21, 22]. These ecosystem elements must work in coordination and towards common CS/CT goals [21, 22] for both the teachers and the students to flourish and realize their potential.

Thus, primary project assessment goals are tri-fold: to create an inclusive, yet rigorous data collection approach that aligns with the principles of our RPP, to enable measurement techniques that are applicable in different school contexts, and develop a methodology that engages key stakeholders. We present our contextual settings and specific research questions for the two schools to show how the tool was applied and the contributions made to our own research.

2 Background

Our work is theoretically grounded in The STEM Ecosystem framework, which emerged from policy [19] and academic research [21] in response to the growing understanding that building student capacity and interest in STEM needs to be addressed systemically. STEM ecosystems strive to provide multiple opportunities for learners to engage in a variety of STEM-related learning activities that enable them to develop knowledge, interest, and skills in STEM disciplines over the course of their youth [26]. When properly coordinated, all of these opportunities create intentionally designed pathways to support equitable STEM learning for all students.

At the heart of the STEM ecosystem are students, whose interactions with other individuals (e.g., peers, mentors, teachers, caregivers) across time and settings, influence their academic and career trajectories [8]. Likewise, teachers and school leaders play integral roles as they create important formal and informal STEM learning opportunities for students. Our model recognizes that a potential key source of STEM learning is the formal schooling environment where all students gain exposure through required coursework. By infusing CS/CT opportunities across core academic courses, self-selection and other barriers to participation are mitigated [12, 20]. Thus, our partnership strategy applies a breadth and depth approach: all middle school students in a school are broadly exposed to CS learning, and then afforded opportunities to deepen and sustain that interest through electives and informal educational activities. Furthermore, outreach to students' homes and communities provided by the school exposes family members to CS activities, bolstering support for student interest outside of school. Combined, all of these experiences build capacity for success in high school and beyond, as students develop positive affect towards computationally-intensive academic and career opportunities.

Research-practice partnerships (RPPs) provide a collaborative framework for curricular development, teacher PD, and coordinated initiatives at the school and district level [7]. The foundation of an RPP is an equal positioning of teachers and researchers, with each partner playing a critical role in jointly identifying important needs, designing possible solutions, collecting and analyzing relevant data, testing solutions, and planning for the sustainability and scale of emerging reform strategies [22]. In other words, RPPs situate researchers and teachers as equal experts, and together they seek to investigate problems of practice and develop compelling solutions that improve outcomes [7]. Employing a design-based research approach was central to the project design because RPPs deliberately elevate teachers' voices. Key features of designed-based research are that the research is iterative, situated within a learning context, collaborative between researchers and teachers, and comparative across situational contexts [1]. The ecosystem perspective serves to address issues of inclusivity and access to CS/CT through a local learning ecology [15]. Measurement techniques that ascertain the myriad of perspectives are important to developing shared understanding when approaching complex problems.

Visual data collection methods such as participatory drawing or concept mapping activities can be useful and inclusive techniques for engaging participants in the research process and eliciting their unique perspectives [29]. These techniques are especially promising for researchers involved in participatory research designs such as RPPs [28], as they promote stakeholder reflection, communication, and empowerment [6]. Motivated by the potential of these practices to intimately engage our RPP stakeholders, we devised an activity grounded upon the project's ecosystem framework. Our ecosystem drawing method draws upon teachers' familiarity with concept maps to create an effective qualitative methodology. We devised two approaches toward the drawing activity to suit the school contexts and address specific research questions across the RPP project.

Drawing and diagramming are a useful qualitative method utilizing visual tools as a means for understanding participants' experiences; assisting in the exploration, communication, and understanding of research participants thinking [16]. The research literature often uses terms such as diagramming, mapping, and drawing interchangeably as they are increasingly popular interdisciplinary data collection approaches [27]. Buckley and Waring [5] posit that diagrammatic representation are invaluable in conceptualizing and representing complex data sets. Sherwood [24] utilized drawing to identify conceptual shifts in teachers' classroom instruction as a result of considering new science standards. Similarly, Ruef [23] analyzed drawings to develop a snapshot of preservice mathematics teachers shifts in what they notice and envision in considering optimized visions of teaching and learning. The Draw a Scientist Task (DAST) is a popular research tool that has been used in science education for over three decades. The tool has provided images of scientists that have been analyzed to develop descriptions of perceptions of scientists sometimes leading to identification of potential interventions to promote changes in perceptions [11]. Diagramming is related to drawing in that research participants relate the features they depict in diagrams to represent aspects of their social world [3]. Our use of drawing or diagramming using a STEM ecosystem model responds to identified research needs with studying learning ecosystems [13], which is a complex set of interconnected elements that are dynamic and non-linear. There is a need to utilize tools that allow one to both identify and monitor relational processes and activities with a complex system. In addition, the drawing activity is also a powerful reflective activity for the teachers which can be used to help clarify a collective vision of where their school is currently (and is going) among the participants.

3 RPP Contexts

Our STEM ecosystem model evolved through a joint commitment between Reedy Creek Middle School (RC) and North Carolina State University (NCSU) to integrate CS/CT into all required science and math classes for repeated exposure to CS/CT concepts and practices in all three grades. In our effort to adapt our model as a scalable, generalizable approach for systematic, school-wide integration of CS/CT into required math and science courses, we formed an RPP with UNC Charlotte (UNCC) and Northridge Middle School (NR). Our network improvement community partnerships [4] are situated within the two largest school districts in our state, with distinctly different student populations, offering comparative contexts for evidence capture, idea testing, and sharing lessons learned.

3.1 Reedy Creek Middle School

The RC RPP team meets regularly for coordination. The middle school is a digital science magnet program with over 800 students, with almost half of whom are from underrepresented ethnic groups in computing (African American, Hispanic/Latinx) situated within the largest school district in the state. During the 2019 – 20 school year, the RPP team launched an initiative to inte grate Snap*!* coding in classrooms across the school. This included the establishment of a core group of teachers at the school to lead the initiative with the help of the NCSU team. Therefore, RPP goals for the school year included building teacher capacity to integrate CT and to strengthen the existing ecosystem.

3.2 Northridge Middle School

The NR RPP between Northridge Middle School (NR) and UNC Charlotte (UNCC) launched in spring 2019, soon after the school formalized as a computer science magnet program. NR has over 700 students, 93% of whom are from underrepresented ethnic groups in computing, and is situated in the second largest district in the state. Prior to the formal launch of our RPP, the university and school had maintained an informal relationship with ad hoc support of after school computing activities. During spring 2020, the school adopted Python as its primary platform, to be integrated across the 6th , 7th, and 8th grade curricula in the 2020 – 2021 academic year. Primary goals for our RPP were to establish trust, create a culture of open dialogue, and to capture data about the barriers and supports within the ecosystem.

4. Procedures and Methodology

The overall purpose of the drawing activity is to capture meaningful data about stakeholder perceptions of the ecosystem through open dialogue. Because each school context differs, and the relationships were at different stages, two distinct approaches were devised. At RC, the partnership is well established, therefore the objectives were to a) assess the current ecosystem as a benchmark of RPP progress, b) to facilitate dialogue about the ideal ecosystem, and c) identify any necessary project refinements to achieve the ideal in the course of the project. The NR partnership was in its initial stages, therefore the objectives were to a) demonstrate our project framework, b) develop a trusting relationship, and c) capture baseline data about the nature of the ecosystem from the perspectives of teachers and administrators.

4.1 Reedy Creek-NCSU RPP

In December of 2019, two researchers of the larger research team from NCSU met with nine members of the school's Digital Science Team (DST). Composed of administrators and teacher leaders who have led CS/CT integration activities for over a year, the DST was selected as a sample of the teacher population at the school because of their intimate involvement with the RPP over the past year. The researchers briefly presented the primary goal of the RPP to create a CS/CT-focused ecosystem, along with an example of a STEM ecosystem. Each team member was then provided with a template consisting of blank bubbles with connecting lines (one large blank bubble in the middle with lines from it connecting to eight smaller bubbles). The participants were then directed to draw or write in as many of the perceived components of the current CS/CT ecosystem at their school. After ten minutes, the researchers collected each graphic artifact and then held an open discussion with the team about their responses. Then, each team member was asked to complete the same procedure for what they perceived would be an ideal CS/CT-focused ecosystem at their school. Graphic data was both collected and analyzed by the same two members of the research team. This strategic approach enabled the researchers to become highly familiar with the data through its collection phase, the iterative process of reviewing and analyzing it, and improved interrater reliability through collaborative analysis. First, the researchers created a table to document the essence of the components listed on each participant's artifact. Similar components were noted as duplicate responses. Then they utilized a whiteboard to condense the data by mapping it into categories and emergent themes, resulting in two aggregate interpretations. According to[8], member checking is an important validation strategy to ensure credibility of findings and that interpretations represent participant views. Thus, both researchers replicated the depictions of the aggregated analysis (current and ideal) from the whiteboard into the original template given in Figure 1. Then the researchers met again with the DST to member-check the data and engage participants in a more in-depth and open-ended discussion of their perspectives.

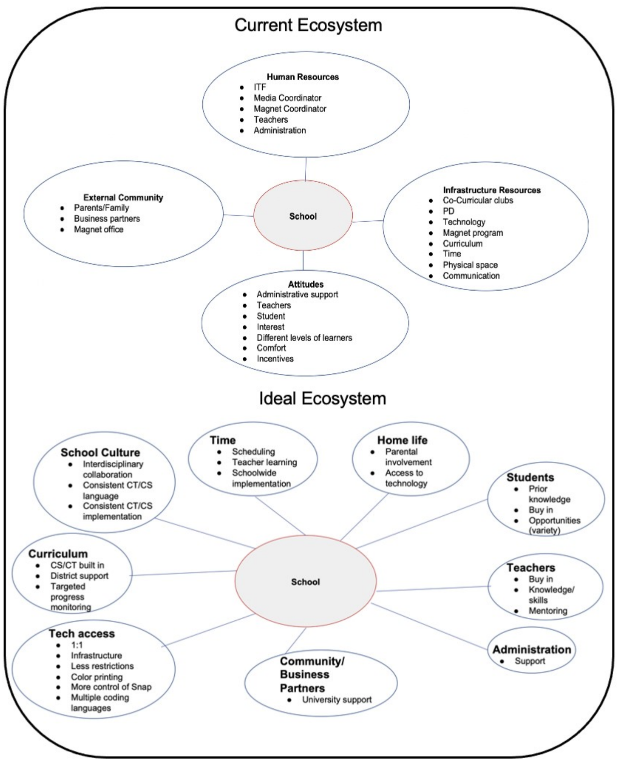

Figure 1: RC Current and Ideal Ecosystem Synopsis

4.2 Northridge-UNCC RPP

All school staff, administrators and teachers participated in a half day professional development event on the university campus, with 60 total participants in the Fall 2019. The drawing activity was conducted at the start of the event, for 45 minutes. During the first 15 minutes, an overview of the model (Figure 2) was shown to the group by a member of the research team, and described to the NR teachers and administrators as an orientation to the RPP. Consent was obtained, allowing 30 minutes for individuals to draw their own diagrams. Participants were given sheets of paper with a blank ecosystem template and asked to draw pluses and minuses in their circles to indicate supports and barriers to including CS into the curriculum. A total of 27 drawings were submitted; a sample is shown in Figure 3. The activity facilitator observed several pairs of participants opting to discuss and draw together. Follow up discussion was facilitated from which contextual notes were obtained for group sense-making.

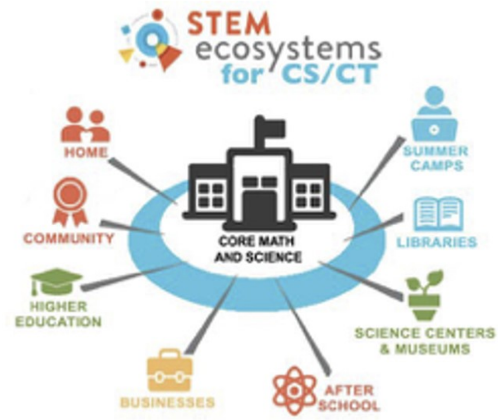

Figure 2: STEM Ecosystem Model

Thematic analysis was conducted with coding conducted by three researchers at UNCC. To systematically 'transcribe' each drawing, a spreadsheet was created. Each drawing was labelled numerically, in no particular order, with each drawing represented on a spread sheet row. The center circle drawing contents were entered first, with all remaining circle contents, including pluses and minuses, entered in clockwise order. A process of open coding [25] was applied to the raw data, which was conducted individually by each researcher, afterwhich consistencies and discrepancies were identi fied [18]. A meeting was conducted with the researchers to discuss discrepancies in coding themes and derive consensus. Indication of either strength or barrier was made based on what was written in the circle, e.g. a plus, a minus, 'support,' or 'barrier.' In cases without indication, the research team coded these as neutral.

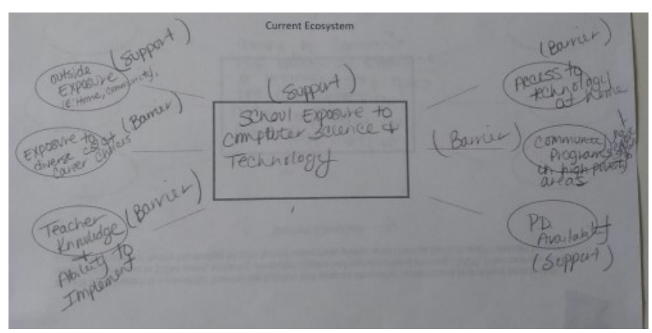

Figure 3: Sample Ecosystem Drawing from Northridge

5 Results

We describe findgings that inform our partnerships, and how the application of the data collection activity served as an effective methodology for data capture and relationship development.

5.1 Reedy Creek Outcomes

5.1.1 Current Ecosystem. After analyzing the drawings from the DST, the following major components emerged consistently across the current ecosystem: human resources, activities, and external stakeholders. The human resources component referred to the specific school staff that planned or implemented digital sciences integration into the school community, including the magnet coordinator, technology coordinator, media specialist, administration, and teachers. These individuals were predominantly charged with doing the work in the ecosystem. The activities component described the current professional development (PD) offerings for teachers to gain familiarity with CT and coding as well as the opportunities for students to engage with the material in class and through extracurricular clubs. The activities were well aligned with the magnet program theme, implemented throughout the curriculum, and fostered interest and engagement by both teachers and students. The external stakeholders component referred to people and entities external to the school, such as business partners and parents, that contributed to the ecosystem by investing their time or expertise. This included support from the university partners.

In describing the current ecosystem, teacher comfort level with engaging in this material and attitudes appeared to be a major success factor to leveling the organizational challenges of trying something new. In particular, the team underscored the importance of the interest, buy-in, commitment, and support from their administrative leadership and fellow teachers. Students were also highlighted as a key partner as they also have differing levels of understanding and buy-in.

Interestingly, access to technology at home was mentioned as an external factor, which could have even stronger implications now given the COVID-19 pandemic and the necessity of remote instruction. Considering their limitations, the team noted how digital tools, time, physical space, and clear communication and expectations could be improved to enhance their ecosystem.

5.1.2 Ideal Ecosystem. DST members envisioned an ideal ecosystem to include the following main components: time, technology access, and stakeholder buy-in. Specific examples from participant's artifacts and through our member checking discussion, demonstrated that DST members believed ample time within the ecosystem would allow for the building of critical resources such as a more coordinated CS curriculum and PD activities. Regarding the theme of technology, district-provided technology is chronically limited in terms of quantity and quality. Thus, an ideal ecosystem would have 1:1 student device availability, and less district-imposed restrictions on the accessibility of materials. Furthermore, the "digital divide" continues to be a common challenge as schools implement more digital-based home assignments. As such, in an ideal ecosystem, DST members voiced that "digital equity" among their students' home access to technology would prevail. Finally, they expressed the importance of buy-in among students, parents, teachers, and administrators. However, they also acknowledged how buy-in can look different for each group. For example, for students, buy-in may be choosing to participate in an optional extracurricular club or activity, whereas for teachers buy-in may be garnered through providing incentive and recognition.

5.2 Northridge Outcomes

Thematic analysis resulted in several codes of features that were grouped into six broad categories, which were then organized into supports, barriers, and neutral as shown in Table 1. Coding for support or barrier was made in cases where a circle was explicitly indicated as such. Overall, there were a total of 56 explicit supports and 53 explicitly noted barriers. A total of 78 features had no indication and were classified as neutral. Across the 27 diagram drawings submitted, the school was written into the center of the drawing in 8 cases, with the center circle left blank in 11 cases. "Students", and "Computer Science" were written into the center circle in three cases each, with "Teachers" in the center circle on two diagram drawings. Based upon follow up discussion, teachers assumed the center circle to be indicative of the most influential element of the ecosystem and were largely uncertain. We interpret this to indicate that they perceive a holistic system, rather than a hierarchical structure of influence.

5.2.1 Supports. The dominant supportive ecosystem component noted was technical resources. With a new designation as a CS coding magnet, ample resources within the school were listed. The most frequently noted resource was the school Maker Space lab. Teachers' enthusiasm and readiness was viewed as a strength within the ecosystem, as were community and parental support to a small degree of frequency.

5.2.2 Barriers. Despite being the second most frequently noted support within the ecosystem, teacher preparation was most frequently indicated as a barrier to integrating CS into the curriculum. The teachers indicated the time required for their preparation, and necessary Professional Development and training to prepare them for integrating CS into the classrooms. An expression of fear, anxiety and lack of confidence was indicated also, undoubtedly related to the pressures from the many demands faced by teachers in a school amidst transition.

Table 1. Northridge Themes of Barriers and Supports

Total Indication Counts	Broad Themes [indication counts]	Examples
Supports [56]	Tech Resources [39]	Maker Space, Chrome Books, Summer Camps, Robotics
	Teacher Preparation [10]	Teachers' interest, Lesson planning/ integration
	Community Support [5]	UNCC Partnership, Industry Partners, Science Museum/Centers
	Parents/Home [1]	Outside exposure at home
	Students [1]	Engagement in class
	Policy [0]	[no policy feature was indicated as a support]
Barriers [53]	Teacher Preparation [17]	Time, Curricular Integration, Training for new technology, Anxiety/Confidence
	Students [11]	Motivaiton, Preparation, Truancy
	Tech Resources [11]	Outdated technology
	Parents/Home [5]	No technology at home
	Policy [5]	Curriculum, Standards alignment
	Community Support [4]	Lack of transportation, Funding support from museums
Neutral [78]	Tech Resources [43]	Apps, Coding courses
	Teacher Preparation [18]	Training, Background
	Community Support [7]	Social
	Parents/Home [4]	Support
	Students [3]	Different learning styles, Comprehension
	Policy [3]	Arts and Science disconnect

Students were a noted barrier, and viewed mainly as an obstacle, with comments about lack of preparation and motivation to engage in CS. Whereas Chromebooks were a commonly noted support, outdated technology was mentioned as a barrier to infusion of CS.

Although the frequency was low, policy may perhaps be the most substantial barrier within the ecosystem, as teachers indicated the curriculum standards present challenges to integration of CS. Lacking access to technology at home is a major equity issue to be addressed.

5.2.3 Neutral. There were a large number of circles without indication of support or barriers. Through discussion with the teachers following the activity, we see the complexity of labeling a feature as an exclusive support or a barrier. Many of the features operate as both a support and a barrier depending upon context. For example, lack of student interest is a noted barrier, yet there is optimism that with engaging teaching strategies, the students' interest and motivation to learn will increase. Many teachers view current barriers as opportunities for development of support, and expressed enthusiasm for enhancing their own awareness of CS/CT to better facilitate student learning.

6 Discussion

This report demonstrates two cases of a novel research methodology to support school-university collaborative research. The graphic data collection tool offers a practical technique for collaborative teams such as RPPs to collectively engage in the research process. In our applications, we employed the technique as a formative assessment tool to elicit practitioner perspectives and a relationship building tool to foster an ongoing dialogue about understanding the ecosystem. This tool is versatile and can be adapted to address multiple problems of practice depending on school and university partners' interests, stage of partnership, and contexts.

Informed by these research activities, we have collectively developed more targeted RPP goals for the upcoming school year. As illustrated by Hendrick et al.'s RPP Effectiveness Framework [14], two important indicators of productive RPP engagement are (1) promoting collaborative decision-making and equitable participation in all phases of the work, and (2) providing research to support improvements in the partner organization. We think the graphic data collection tool exemplifies these features by creating opportunity to capture multiple perspectives in an active dialogue about enhancing the ecosystem. The versatility of this graphical technique allows us to continually assess the ecosystem over time [17], documenting growth and collectively identifying strategies to support its growth.

6.1 Impact on Established Partnership

Eliciting the practitioners' perspectives of the ecosystem through the graphic drawing method was a necessary step to help the research team identify its current state and to understand where to focus efforts for continuous improvement. The drawing activity enabled us to stretch beyond the routines of regular feedback meetings, by giving us a creative means for open discussion. The results from our studies at Reedy Creek demonstrated a need to more fully integrate students' home lives, enhance family engagement, provide ongoing teacher PD and interdisciplinary collaborations, and plan for consistent integration across each grade level.

The methodology achieved our goals of capturing information about the current ecosystem from multiple teacher perspectives and further refine our understanding of the shared vision. The use of the graphic data collection tool was transformative in our partnership. Uses of the graphic tool facilitated a departure from routine conversations towards more meaningful dialogue, combatting stifled dialogues [15].

6.2 Impact on Developing Partnership

It is not surprising that continuing barriers were noted, given that Northridge was a newly established CS magnet school. Teacher preparation for implementing CS into the classrooms was a primary concern, since the majority of them had no prior exposure to CS. As a result of these formative findings, we initiated more frequent and accessible professional development options, e.g., full day Python workshops, and provided additional training and support for 'Lead Teachers' to serve as subject matter experts for classroom support.

Engaging the educational practitioners in the drawing activity enabled us to launch our partnership at Northridge by setting an expectation of collaboration and open dialogue between the teachers and research team. The activity catalyzed teacher engagement within a large group by providing an avenue for dialogue and participatory problem solving, a key feature of RPPs [1,2]. We observed the current perspectives of the ecosystem, and created a benchmark from which to gauge changes and direct our future vision. The application of the drawing tool enabled us to share our theoretical framework, build trust and open dialogue, and understand the teacher perspectives.

7 Conclusion

This experience report demonstrates how a visual data collection methodology can be utilized in multiple RPP contexts with a variety of stakeholders. The approach offers a rigorous yet flexible evaluation and research technique, with a creative delivery mode designed to align with the RPP philosophical framework. It is an engaging way of creating and sustaining meaningful dialogue between partnerships that promote understanding and shared vision setting. It is versatile and can be utilized at various stages of RPPs, whether to build relationships, or to set new course directions. This qualitative approach fosters conversations and collaborations of complex educational contexts, while simultaneously providing research and evaluation metrics. We plan to repeat this methodology on a deeper level with teachers and administrators, and to deploy this method with parents and students.

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REFERENCES

[1] Terry Anderson and Julie Shattuck. 2012. Design-based research: A decade of progress in education research? Educational researcher 41, 1 (2012), 16–25.

[2] Tiffany Barnes and George K Thiruvathukal. 2016. The need for research in broadening participation. Commun. ACM 59, 3 (2016), 33–34.

[3] Alison Bravington and Nigel King. 2019. Putting graphic elicitation into practice: Tools and typologies for the use of participant-led diagrams in qualitative research interviews. Qualitative Research 19, 5 (2019), 506–523.

[4] Bryk, Anthony S., Louis M. Gomez, and Alicia Grunow. "Getting ideas into action: Building networked improvement communities in education." Frontiers in sociology of education. Springer Netherlands, 2011. 127-162.

[5] Charles A Buckley and Michael J Waring. 2013. Using diagrams to support the research process: Examples from grounded theory. Qualitative Research 13, 2 (2013), 148–172.

[6] Mirian Calvo. 2017. Reflective drawing as a tool for reflection in design research. International Journal of Art & Design Education 36, 3 (2017), 261–272.

[7] Cynthia E Coburn, William R Penuel, and Kimberly E Geil. 2013. Practice Part nerships: A Strategy for Leveraging Research for Educational Improvement in School Districts. William T. Grant Foundation (2013).

[8] National Research Council et al. 2015. Identifying and supporting productive STEM programs in out-of-school settings. National Academies Press.

[9] John W Creswell. 2013. Qualitative Inquiry & Research Design Choosing Among Five Approaches. Sage Publications. SAGE.

[10] Peggy Doerschuk, Cristian Bahrim, Jennifer Daniel, Joseph Kruger, Judith Mann, and Cristopher Martin. 2016. Closing the gaps and filling the STEM pipeline: A multidisciplinary approach. Journal of Science Education and Technology 25, 4 (2016), 682–695.

[11] Donna Farland-Smith. 2017. The Evolution of the Analysis of the Draw-a-Scientist Test. SensePublishers, Rotterdam, 171–178. https://doi.org/10.1007/978-94-6300- 875-4_15.

[12] C. Fancsali, L. Tigani, P. Toro Isaza & R. Cole (2018, February). A landscape study of computer science education in NYC: Early findings and implications for policy and practice. Proceedings of the 49th ACM Technical Symposium on Computer Science Education, 44-49.

[13] Marijke Hecht and Kevin Crowley. 2020. Unpacking the learning ecosystems framework: Lessons from the adaptive management of biological ecosystems. Journal of the Learning Sciences 29, 2 (2020), 264–284.

[14] Erin C Henrick, Paul Cobb, WR Penuel, K Jackson, and Tiffany Clark. 2017. Assessing research-practice partnerships: Five dimensions of effectiveness. New York, NY: William T. Grant Foundation (2017).

[15] Ann Hodgson & Ken Spours (2015) An ecological analysis of the dynamics of localities: a 14+ low opportunity progression equilibrium in action, Journal of Education and Work, 28:1, 24-43, DOI: 10.1080/13639080.2013.805187

[16] M Horne, S Masley, and J Allison-Love. 2017. Drawing as a research tool: what does it add?. In https://www. rcn. org. uk/professional-development/research-and innovation/research-events/rcn-2017-research-conference. Royal College of Nursing.

[17] Ioana Literat. 2013. "A pencil for your thoughts": Participatory drawing as a visual research method with children and youth. International Journal of Qualitative Methods 12, 1 (2013), 84–98.

[18] Janice M Morse, Michael Barrett, Maria Mayan, Karin Olson, and Jude Spiers. 2002. Verification strategies for establishing reliability and validity in qualitative research. International journal of qualitative methods 1, 2 (2002), 13–22.

[19] STEM Founders Network. 2018. NC STEM Ecosystem: Retrieved from Driving the Future. http://stemecosystems.org/ecosystem/nc-stem-ecosystem/

[20] M. Webb, N. Davis, T. Bell, Y. J. Katz, N. Reynolds, D. P. Chambers & M. M. Sysło (2017). Computer science in K-12 school curricula of the 2lst century: Why, what and when?. Education and Information Technologies, 22(2), 445-468.

[21] William R Penuel, Tiffany L Clark, and Bronwyn Bevan. 2016. Infrastructures to Support Equitable STEM Learning across Settings. Afterschool Matters 24 (2016), 12–20.

[22] William R Penuel, Barry J Fishman, Britte Haugan Cheng, and Nora Sabelli. 2011. Organizing research and development at the intersection of learning, implementation, and design. Educational researcher 40, 7 (2011), 331–337.

[23] Jennifer Ruef. 2020. Visions of the possible: Using drawings to elicit and support visions of teaching mathematics. Mathematics Teacher Educator 8, 2 (2020), 59–80.

[24] Carrie-Anne Sherwood. 2020. "The Goals Remain Elusive": Using Drawings to Examine Shifts in Teachers' Mental Models Before and After an NGSS Professional Learning Experience. Journal of Science Teacher Education (2020), 1–23.

[25] Anselm Strauss and Juliet Corbin. 1998. Basics of qualitative research techniques. Sage publications Thousand Oaks, CA.

[26] Kathleen Traphagen and Saskia Traill. 2014. How cross-sector collaborations are advancing STEM learning. Los Altos, CA: Noyce Foundation (2014).

[27] Muriah Umoquit, Peggy Tso, Tünde Varga-Atkins, Mark O'Brien, and Johannes Wheeldon. 2013. Diagrammatic elicitation: Defining the use of diagrams in data collection. The Qualitative Report 18, 30 (2013), 1–12.

[28] Lisa M Vaughn, Jennifer R Jones, Emily Booth, and Jessica G Burke. 2017. Con cept mapping methodology and community-engaged research: a perfect pairing. Evaluation and Program Planning 60 (2017), 229–237.

[29] Liliane Cambraia Windsor. 2013. Using concept mapping in community-based participatory research: a mixed methods approach. Journal of Mixed Methods Research 7, 3 (2013), 274–293.