Methods and Outcomes of the NSF Project on Synthesizing Environments for Digitally-Mediated Team Learning

Ronald F. DeMara[1a], Joseph E. Beck[2], Laurie O. Campbell[1b], Richard Hartshorne[1b], Samuel Spiegel[3], Zhongzhou Chen[1c], Melissa Dagley[1d], Eloy Hernandez[1e], Tian Tian[1f], Julie Donnelly[1g], Adrian Tatulian[1a], Shadi Sheikhfaal[1a], Hossein Pourmeidani[1a], Hans Esteves[1b], and Tara Gibson[1b]

{[1a]Department of Electrical and Computer Engineering, [1b]Department of Learning Sciences and Educational Research, [1c]Department of Physics, [1d]Center for Initiatives in Science Technology, Engineering, and Mathematics, [1e]Department of Chemistry. [1f]Department of Mechanical and Aerospace Engineering, and [1g]Division of Digital Learning, University of Central Florida, Orlando, FL 32816}
{[2] Trefny Innovative Instruction Center, University of Colorado Mines, Golden, CO 80401}
{[3] Department of Computer Science, Worcester Polytechnic Institute, Worcester, MA 01609}

Abstract

This poster paper describes the authors' single-year National Science Foundation (NSF) project DRL-1825007 titled, "DCL: Synthesis and Design Workshop on Digitally-Mediated Team Learning" which has been conducted as one of nine awards within NSF-18-017: Principles for the Design of Digital STEM Learning Environments. Beginning in September 2018, the project conducted the activities herein to deliver a three-day workshop on *Digitally-Mediated Team Learning* (*DMTL*) to convene, invigorate, and task interdisciplinary science and engineering researchers, developers, and educators to coalesce the leading strategies for digital team learning. The deliverable of the workshop is a White Paper composed to identify one-year, three-year, and five-year research and practice roadmaps for highly-adaptable environments for computer-supported collaborative learning within STEM curricula. As subject to the chronology of events, highlights of the White Paper's outcomes will be showcased within the poster itself.

Collaborations during this workshop identified near-term and future research directions to facilitate adaptable digital environments for highly-effective, rewarding, and scalable team-based learning. An emphasis of the workshop included the personalization of collaborations among diverse learners by automating the identification and utilization of learners' efficacies and knowledge gaps to create complementary collaborative teams that maximize avenues for peer teaching and learning. The workshop targeted the utilization and efficacy of next-generation learning architectures through a focus on instructional technologies that facilitate digitally-mediated team-based learning. These included technical objectives of: (1) identifying new research in learning analytics required to automate more optimal composition, formation, and adaptation of learner design teams; (2) detecting advances in physical and virtual learning environments that can achieve more effective and scalable observation and assessment of learner teams in real-time; (3) distinguishing data mining techniques to leverage devices such as monitors, trackers, and automated camera observations to increase efficacy of team learning; and (4) extending collaborative learning technologies to broaden participation and achievement of diverse learner groups, including women and other underrepresented and underserved populations in STEM. The poster will present the results of the workshop for the design, development, implementation, and evaluation of digitally-mediated teams.

1.0 Introduction

As a joint effort between the University of Central Florida, the Worcester Polytechnic Institute, and the Colorado School of Mines, the Digitally-Mediated Team Learning (DMTL) workshop took place at the University of Central Florida between March 31st and April 2nd of 2019. The purpose of this workshop was to convene researchers, educators, and practitioners to advance transformative pedagogical approaches for technology-enhanced team learning within STEM disciplines at both the secondary and college-level. Further, interdisciplinary data science and STEM researchers, developers, and educators identified future research directions towards adaptable digital environments for effective and scalable team-based learning in classroom settings, with a focus on personalized learning for diverse learners.

The effort was supported by the National Science Foundation (NSF) Division of Research on Learning (DRL) initiative "NSF-18-017: Principles for the Design of Digital Science, Technology, Engineering, and Mathematics (STEM) Learning Environments" [1] through grant DRL-1825007 "Synthesis and Design Workshop: Digitally-Mediated Team Learning" [2]. The objective of this workshop was to determine one-year, three-year, and five-year plans for key research and practice considerations related to the integration of highly-adaptable digital learning environments in STEM teaching and learning, as outlined in a White Paper commissioned by NSF on those topics. The White Paper provided a unifying roadmap for the future of the field, including the design, development, implementation, and evaluation of digitally-mediated team-based pedagogies, and was composed jointly by the organizers and participants of the workshop, to capture the essence of the diverse interactions taking place during the workshop.

1.1 Vision of Change

Team design, *group problem solving*, and *project collaboration* have always been prominent, and even defining, attributes of STEM education, as common labs, projects, and even Senior Design courses, rely heavily on team-based learning. Especially in the last two decades, and into the foreseeable future, team design skills are receiving increasing focus as the complexity of science and engineering marches ever forward [3]. This rising tide of complexity necessitates future graduates within STEM fields to function effectively as specialists who work together closely with diverse populations during product development and research. Thus, the advancement of both mobile and forward-looking educational technologies demonstrating the potential to support team-based instruction is vital and broadly-impacting across STEM fields.

The goals of this workshop were pursued through the following vision of change:

> ***Advance next-generation learning architectures by convening researchers, developers, and educators to participate in the following four synergistic workshop tracks for team-based instructional innovations:***
>
> > ***Track 1: Facilitating Team Learning in Real-time via Online Technologies***
> >
> > ***Track 2: Personalizing Collaborative Learning through Analytics***
> >
> > ***Track 3: Supporting Digital Teams using Active Pedagogical Strategies***
> >
> > ***Track 4: Empowering Equitable Participation through DMTL***

The track-based organization of the DMTL Workshop maximized the likelihood of reaching the needs of every learner by explicitly targeting all aspects of the team-learning process. Tracks 1 and 3 focused on identifying specific technological applications and pedagogical strategies to support the delivery of high-quality team-based instruction, with an emphasis on real-time monitoring of student performance: Track 1 focused on developing new technological platforms, or leveraging existing platforms to achieve this goal, while Track 3 focused on embedding proven and emerging pedagogical strategies in team-based learning. Track 2 sought to optimize the initial team formation based on the learner profile (strengths and weaknesses) of each student, as established through data mining of assessments. Finally, Track 4 focused on developing strategies for equitable learning and inclusion of all students, especially those who may traditionally be underserved or underrepresented in STEM fields. The track-based approach was expected to convene experts from already-established fields, such as Computer-Supported Collaborative Learning (CSCL), Team-Based Learning (TBL), and Learning Analytics (LA), who may rarely attend conferences outside of their specialization, with the goal of both broadening the views of the participants and producing synergy both within and between workshop tracks.

1.2 Outline of Manuscript

Section 2 of this paper will outline the participants' recruitment process for the DMTL Workshop; Section 3 will provide a comprehensive overview of the Workshop purpose, tracks, and activities; Section 4 will present the template-based approach implemented as a tool for organizing Workshop flow and organization of data for integration into the NSF Whitepaper; and finally, Section 5 will present outcomes obtained to date and conclude the paper.

2.0 Promoting Workshop Participation and Recruitment Strategies

A variety of measures were taken by the workshop organizers to publicize the workshop and recruit expert participants. These efforts included the creation of a website and social media channel, development and maintenance of a continually evolving mailing list, use of an expertise profile and position abstracts, and awarding of travel stipends to eligible participants.

2.1 Publicity Mechanisms

To begin the publicizing of the DMTL Workshop, a website was established (see https://www.digital-learning-teams.com/). The website included a variety of Workshop details, including a general overview, descriptions of the scope of each track, invited speakers, a Workshop agenda for each day, and FAQ's. This information was provided as concise text and organized in such a manner that potential participants could quickly determine whether the scope of the Workshop has relevance to his or her discipline. The website also provided a detailed account of the application and registration process for the Workshop (summarized in a flow chart).

To publicize the website, a mailing list of experts who may potentially be interested in participation was developed, updated, and maintained throughout the recruitment process. The mailing list primarily consisted of authors of recent journal/conference papers in fields such as

CSCL, TBL, LA, Learning Sciences, etc., as well as participants on existing listservs relating to areas associated with digitally-mediated team learning. Compiling the mailing list required several hours of research as well as necessary connections with editors/leaders in these fields; however, it was an essential task as it allowed the program committee to reach over one thousand potential participants. Mailing list members were sent an e-mail briefly describing the impetus for, and the nature of, the DMTL Workshop along with a link to the previously described website, where they were able to access additional information. The e-mail was sent twice, once well in advance of proposal priority deadline, and again just before the priority deadline. A formula-based tracking spreadsheet was maintained to keep track of inquiries, participant responses, and management of the content and dissemination of future e-mails.

2.2 Provision of Travel Stipends

As a tool for incentivizing expert attendance and participation at the workshop, 50 travel stipends were offered to eligible participants (i.e., U.S. citizens or permanent residents, per U.S. government regulations). The stipend amount was established at $500 to cover the cost of travel, lodging, and meals for in-state attendees, and $800 for out-of-state attendees. The condition for being awarded a travel stipend was the submission of a position abstract, outlining a topic of expertise relevant to at least one of the four workshop tracks. With the provision of the stipend, three registration deadlines were set: a priority deadline, followed by a regular deadline for stipend consideration, and then a final deadline for all participants, regardless of whether a stipend was awarded.

2.3 Registration Flow

The registration flow differed for participants and was dependent upon whether a travel stipend was requested. If no stipend was requested, participants were required to only complete an expertise profile, gauging their level of expertise as related to at least one workshop track. However, if a travel stipend was requested, applicants needed to develop and submit a position abstract and, once the stipend was granted, submit a W9 form to receive funds. All selected
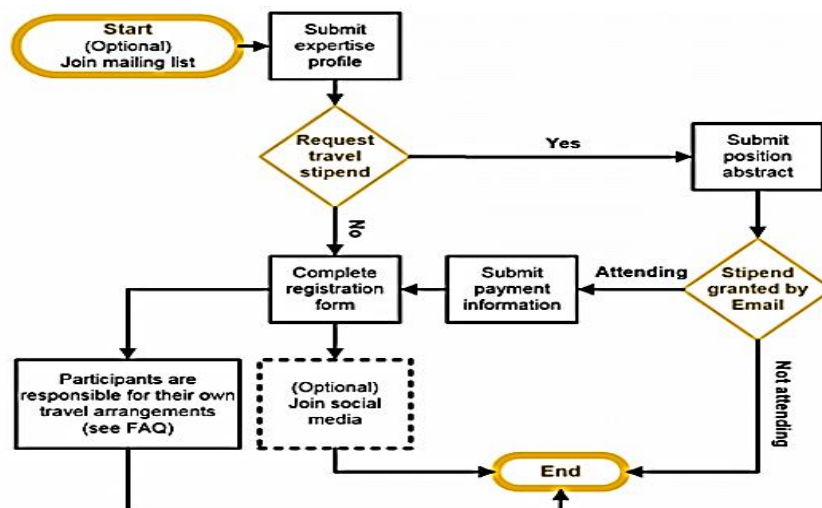

Figure 1: Registration Flowchart.

My preferred primary track:

[⌄]

My preferred secondary track:

[ ]

Title of my own publication that is closely related to my primary track preference:

[ ]

Title of my own publication that is closely related to my secondary track preference:

[ ]

I have taught courses in the following delivery modes (check all which apply):
☐ In-person only lecture
☐ Mixed-mode or blended delivery of online and face-to-face content
☐ Fully online
☐ Others

I have used real-time collaboration tools such as Google Docs, Socrative, InteDashboard, or others, within my classroom:
○ Never
○ Rarely
○ Considering it
○ Occasionally
○ Regularly

I have used out-of-class Project Team collaboration tools such as CATME, RateMyTeam, etc. within courses I teach:
○ Never
○ Rarely
○ Considering it
○ Occasionally
○ Regularly

I am advancing Learning Analytics techniques in my research or student analysis:
○ Never
○ Rarely
○ Considering it
○ Occasionally
○ Regularly

Participation Interest:
☐ I am interested to actively participate in breakout sessions.

Posting Consent:
☐ I understand that Position Abstracts may be posted on digital-learning-teams.com website.

White Paper:
☐ I understand that portions of participants' contributions appear in the White Paper delivered to NSF.

Figure 2: Excerpt of the Expertise Profile

applicants were also required to submit an online registration form, which simply confirmed all dates in which they were available to participate. For the convenience of applicants, a flowchart illustrating the registration flow (Figure 1) was made available on the website.

2.4 Expertise Profile

The expertise profile was available as an online form on the DMTL website, and it was required that all applicants completed the form to gauge both their qualifications to participate in the Workshop and their ability to contribute to the White Paper. The expertise profile requested basic applicant information and requested the selection of at least one Workshop track to focus
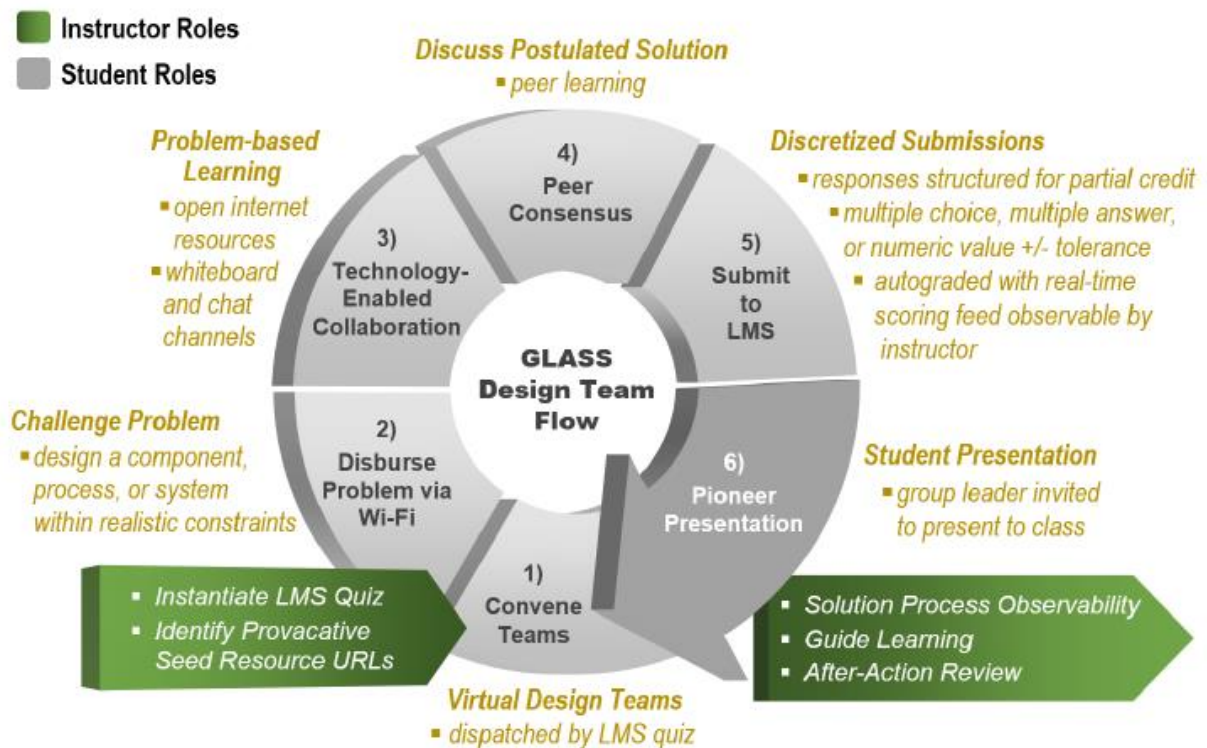
Figure 3: Sequence of DMTL instructor and student roles.

their participation. To demonstrate competence in this track area, applicants were asked to cite at least one of their publications that related to the aim and scope of their selected track. Finally, the applicants were asked a series of survey questions regarding the level of their knowledge and use of educational technologies, learning analytics, emerging and innovative pedagogies, etc. Additionally, the expertise profile confirmed the applicant's interest to participate in all workshop activities (including contributing to the White Paper) and requested their interest in receiving a travel stipend. Figure 2 shows a portion of the expertise profile.

2.5 Position Abstract

Position abstracts were required from all participants requesting a travel stipend. The position abstract provided more in-depth information about an applicant's qualifications, beyond the expertise profile, thus allowing the Program Committee to select the most qualified applicants for the 50 available travel stipends. Besides aiding in the selection process, position abstracts were also used for shaping the workshop agenda, identifying relevant panelists and speakers, and contributing directly to the White Paper. The following instructions, outlining the requirements and considerations for position abstract development, were provided to all applicants:

Position Abstracts should begin by describing the authors' current and planned research, then extend it to recommend approaches that improve the community's shared understanding of DMTL. All Position Abstracts should address the following essential questions:

I. Key Challenges: Which challenge(s) related to digitally-mediated team learning does this Position Abstract address?

II. Maturity: Has the approach been implemented? Under what circumstances? What were the outcomes thus far (in terms of learning gains, student perception, etc.)?

III. Research Direction: What is the promising research direction for this topic?

IV. State-of-the-Art: Across the community, what is the current state-of-the-art for this research direction?

Further, a downloadable template for the position abstract was provided for all participants and was accessible from the DMTL website. Applicants were required to include one to three pages of text related to the four essential questions. Upon completion, applicants were to upload their document through the EasyChair conference management system. Each abstract was then assigned to a Program Committee member, based on track, who then reviewed the abstract and determined whether an offer of a travel stipend was warranted. Those who were not offered a travel stipend were still eligible to attend, and received a link outlining the registration process.

3.0 Overview of DMTL and the DMTL Workshop

3.1 Opportunities for DMTL to advance STEM Learning

The current research in DMTL was initiated as a synchronous problem-based learning spin-off of a project on lockdown digitized assessment conducted by the Investigators [4]. The current research was initiated to investigate viable approaches to integrating student design teams into in-class activities to obtain and acquire the skills required to *design a system, component, or process*, and to *function on multi-disciplinary design teams*, which are an ABET accreditation criteria for engineering degree programs. As depicted in Figure 3, DMTL utilizes one such problem-based learning approach, whereby students acquire expertise while applying skills in solving open-ended problems based upon some trigger content. Further, an increase in proficiency in multidisciplinary design teams was sought by immersing students in alternate problem-solving strategies of their peers, while simultaneously encouraging the development of team interaction and other soft skills. The primary objective of DMTL is to provide students and instructors with an effective technological and pedagogical framework for use during large group instructional sessions. In addition to the benefits to the learner, DMTL provides the instructor with a dynamic view of the learning process, student conceptualizations of content, and challenges associated with specific topics. This information allows the instructor to intervene and reiterate, elaborate, and reinforce concepts that require attention, perhaps by providing additional explanation or examples. DMTL also assists instructors with managing time more effectively and efficiently within the whole-group instructional session, while also gaining more in-depth knowledge and understanding of unique attributes of student problem-solving approaches.

Recently, numerous technology-based tools have become available to facilitate real-time, in-class online collaborations [5-9]. The integration of some of the most rudimentary of these tools, such as Online Collaborative Document/Spaces (e.g. Etherpad) and LMS-based tools (e.g., Canvas, Moodle), into teaching and learning environments are becoming increasingly ubiquitous. Etherpad, for example, is a free, collaborative online text-based editor, allowing
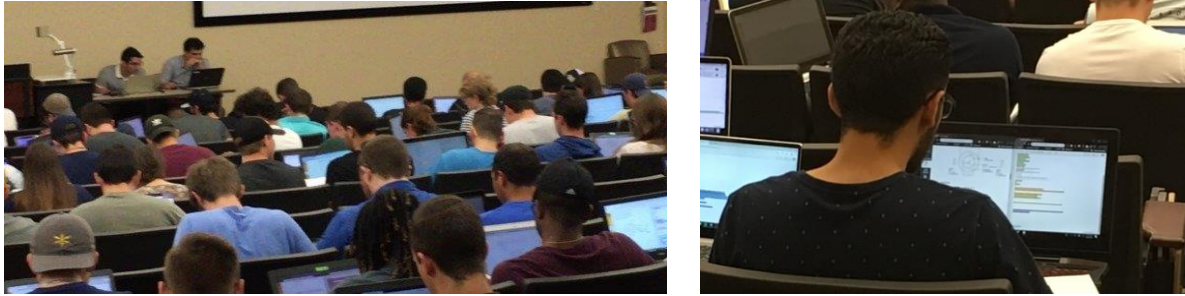
Figure 4: (Left) Instructors and students conducting a DMTL Activity; (Right) Student uses Etherpad within a computer-supported collaborative learning exercise during the authors' undergraduate course face-to-face meeting session.

participants to edit text documents simultaneously while also seeing edits of collaborators, in real-time. Etherpad displays each participant's communication using a unique font highlighting color so that their contributions are differentiated and color-coded, alongside a chat window, which allows for live discussions during the text editing process. One feature of Etherpad that is valuable for design teams is that color-coded traceability allows for documentation of individual contributions throughout the team-based learning event.

Furthermore, Etherpad does not require students to sign-up for an account to utilize the tool, resulting in decreased logistics for classroom integration. Traceability, built-in chat windows, customization for enabling/disabling collaborative annotations, and other functionality are critical technological features for the facilitation of DMTL. The instructor facilitates the DMTL flow by constructing the team learning activity through the creation of an assessment within the course's existing LMS assessment tool. Once a design team concurs that their results are complete, they submit their answers to the Learning Management System (LMS) for auto-grading and score-recording in the grade book. Credit is earned by correctly answering each designated question sub-part, which provides partial credit, a critical aspect of questioning in STEM. Throughout the team design activity, the instructor monitors assignment progress online in real-time, including windows for each design team, illustrating a solution draft as it is constructed, and allowing for providing feedback via each group's designated chat channel. Figure 4 (right) shows a student using Etherpad and the course LMS to share resources, discuss their approach to the problem, and reach a consensus when ready to submit for grading. Figure 4 (left) shows students conducting DMTL with their laptop, with instructors and GTAs guiding students from the front desk.

3.2 DMTL Workshop Overview

The two-and-a-half-day workshop addressed the design, development, implementation, and evaluation of DMTL in the K-20 educational landscape. The workshop flow which was used is outlined in Figure 5. The initial half-day of the workshop consisted of technical overview and networking activities which commenced on Sunday afternoon. These included an optional poster session for those wishing to present their Position Paper in a poster format. The poster session also provided an optional social mixer while allowing other participants to arrive into Orlando that evening. On Monday, the Workshop sessions commenced after a keynote address spanning
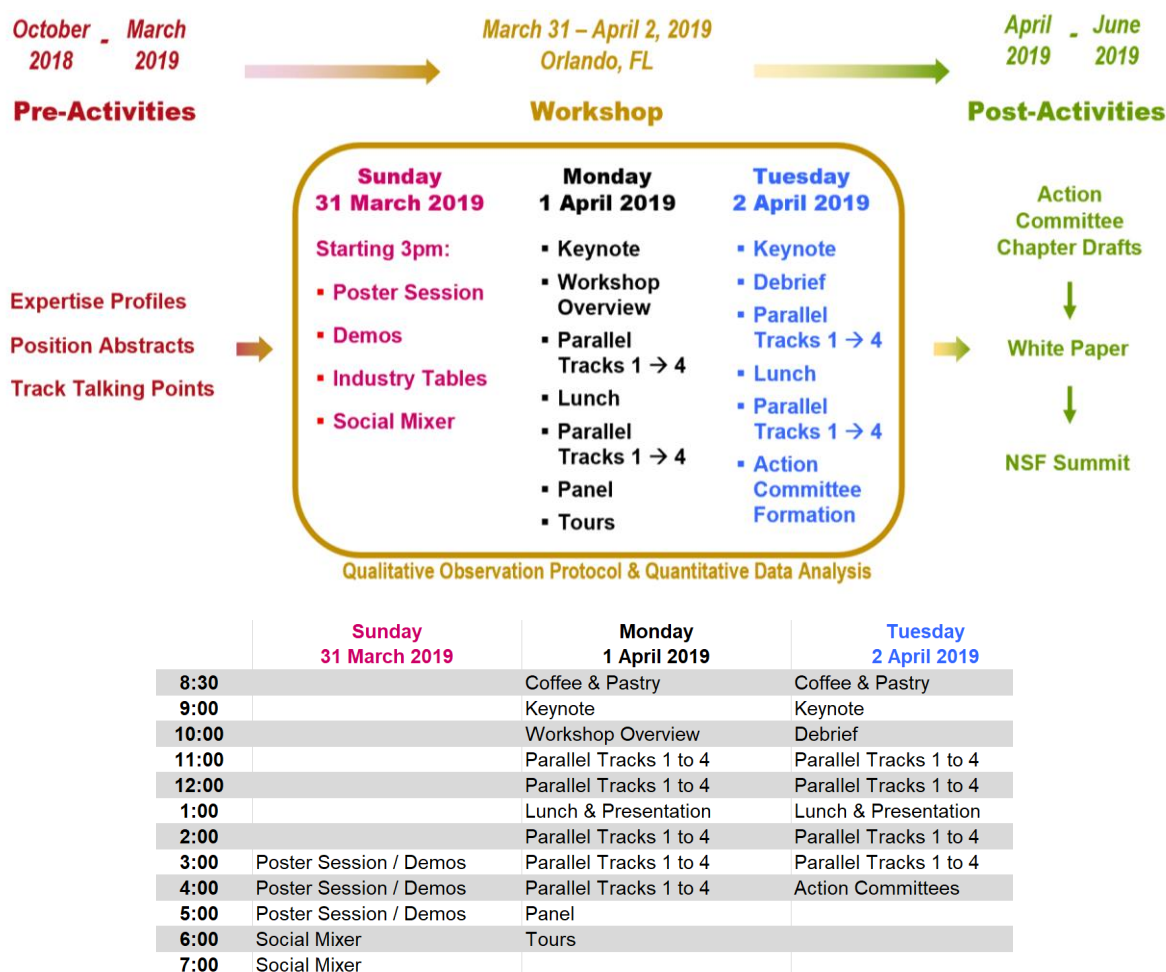
Figure 5: Workshop Graphical Agenda and corresponding Daily Program Structure.

all four tracks and outlook of the field to motivate the Workshop. Parallel tracks continued throughout the day. Members of the Program Committee who served as the Track Chairs also designated two breakout sessions from each track so that elements of the White Paper received sufficient time to be emphasized. The day ended with a tour of new active learning space infrastructures and facilities that could support various aspects of DMTL. Tuesday's sessions began with a keynote address followed by a track debrief by each track chair to the entire workshop. The workshop breakout sessions commenced after a Reflection Debrief having emphasis on trends and progress made and areas to focus the remaining time to maximize the participants work together. After parallel tracks concluded, there was the formation of action committees to complete the remaining steps needed after the Workshop. It is important to point out that a Qualitative Observation Protocol and Quantitative Data Analysis were conducted on Monday and Tuesday, as described below. Post-workshop activities consisted of remote completion of chapter drafts for the White Paper report. The White Paper was disseminated at the *NSF Summit on Future Digital STEM Learning Environments* held in June 2019.

3.3 Intellectual Merit and Broader Impacts of the DMTL Workshop

The DMTL Workshop coalesced significant knowledge related to the utilization of learner design teams in instructional settings. As mentioned, its tracks have informed both near-term and future research related to: 1) harnessing learning analytics in STEM for optimal team formations; 2) real-time observation and assessment with learner teams; 3) data-mining tracking and monitoring data for team learning; and 4) broadening and strengthening the participation of underrepresented populations in team learning. The explorations and subsequent outcomes related to these topics are of significant interest to STEM researchers, educators, and practitioners, as they possess potential to inform the development of scalable, sustainable, and transportable educational solutions for developing team learning through digital means. The White Paper and other dissemination efforts (website, conference presentations, journal publications, etc.) resulting from the DMTL Workshop provide a roadmap for future STEM research related to the design, development, implementation, and evaluation of digitally-mediated teams in diverse instructional settings. Further, the outcomes of this workshop could lead to the advancement and development of new and emerging educational approaches in STEM teaching and learning.

The broader impacts of the DMTL Workshop directly connect to both national and societal goals of improving STEM instruction to develop a stronger national STEM workforce. The workshop united faculty and related industry leaders with expertise in various STEM subjects, including Data Analytics, Data Mining, and Instructional Design & Technology, as well as underrepresented populations, with the goal of identifying pedagogical approaches to facilitate and strengthen digitally-mediated team learning. The workshop contributed to future cross-networking and co-constructing among the attending experts, as they continue to investigate aspects of digitally-mediated team development in STEM. Workshop activities resulted in the previously mentioned White Paper, an Executive Summary, infographic, images, videos and a website to maximize the outreach of themes addressed during the workshop. The constructive broader impact of the resulting White Paper was its highlighting of technical topics to be prioritized for future funding to advance the competitiveness of the U.S. with respect to STEM education and economic vitality. Dissemination of the findings from the workshop include social, traditional, and popular media outlets, and the outcomes of the workshop will benefit researchers, educators, and practitioners from multiple disciplines. Further reaching, the public will be informed of digitally enhanced systematic approaches for forming and designing digitally-mediated design teams in STEM that will broaden underrepresented participation.

The social media plan for disseminating information involved Twitter and YouTube. Hashtags for the workshop appeared on the workshop website. In the three months prior to the event, anticipation posts were made which included some of the hashtags of NSF and the NSF CIRCL Center. As derived from the workshop, the event videos were posted to the outcomes of the research and work being conducted. Due to multi-disciplinary and multi-university representation, the social media dissemination influenced a broad and crosscutting release. Through a pre-established internship program, a social media and digital media undergraduate student implemented the plan.

Table 1: Anticipated data collection metrics and their corresponding objectives.

Approach	Objective	Follow-Up	Data Type
Verbal Interaction Diagrams	Social process Interaction	Analyzed for equitable participation	Round table diagram protocol - quantity and flow of interaction
Discourse Observation Protocol	Leadership/Observer/ Participant	Identify consensus on topic priorities	Quality and types of interactions protocol
Video	Content Analysis Interactions to Triangulate Quantitative Data and Outcome Paper	Available in the event of missing data regarding recommendations from track	Content Analysis for Themes and Interactions
Daily Survey (After each Day)	Formative and Summative Assessment of Interaction and Progress	Tracked and reported in White Paper	Likert Scale Open-Ended Response
One-Minute Cards	Unanswered Questions and Summary Cards	Verify with Track chair for resolution	Open-Ended Response

Table 1 lists the types of information that was collected from the workshop, which included: the position papers of participants, discourse process data, video, and participant's reflection. Collection and analysis of both qualitative and quantitative data provided a detailed understanding of the process and dynamics of the workshop, as well as helping to realize its outcomes. Novel data collection techniques were leveraged to gather the desired information from the workshop using video tracking. These were developed into an observation protocol to collect qualitative data on the social processes observed, as well as supervision of the analysis of the process and interaction data.

3.4 DMTL Workshop Track Outlines

This section identifies the guiding questions in each track, as well as track aims and scope.

3.4.1 Track 1: Facilitating Team Learning in Real-time via online Technologies
The focus of Track 1 included the facilitation of team learning in real-time via online technologies. Primary topics of Track 1 included the following:

- Design of online instructional environments for engaging, observing, and assessing STEM design and problem-solving teams in real-time;

- Specification of instructional technologies that enhance the traceability of activities within learner teams, advanced mechanisms for integrated and automated scoring, and annotation/organization of feedback; and

- Identification of standardized interfaces for learning management systems and defining/outlining characteristics of transportable formats/clearinghouses for problem banks.

Sample guiding questions for Track 1 included:

- How is the interaction between the instructor and student teams supported when using the proposed real-time collaborative technologies?
- What platforms (e.g., Canvas, Socrative, Edupad) are being targeted with this approach? How can strategies be made adaptable to different platforms?
- How are students being monitored/graded in real-time? What is the cost (e.g., in terms of grader hours) of scaling up to a larger setting?

Theme 1A: Activity Authoring
- Which types of STEM design and problem-solving activities are envisioned and some archetypes?
- Which of those archetypes are prioritized at 1,3,5 years to leverage a layered development flow?
- How to create clones, handle solution visibility, and content reuse?
- Is a Respondus-style converter facility helpful to create/maintain authored activities?

Theme 1B: Student-Facing Delivery
- What would suitable and even the ideal student-facing user interfaces for DMTL look like?
- What are essential widgets for a student-facing interface: e.g. raise hand, bannering, balloting, pin note, up-voting?
- How do learners nominate team leaders or MVPs? e.g. pick lists, ratings, blinded vs. open, or support a range of options?
- What are some state-of-the-art tools today for DMTL to consider for further inspiration?

Theme 1C: Instructor Orchestration
- How should instructor-facing user interfaces for DMTL operate and which features would they provide?
- How to support instructor observability/moderation of individual teams and the overall activity, and what are 'operator loading limits' to do so?
- After action review should have which features? e.g. are playback and freeze modes of session activities beneficial?
- Which Team Management features from semester-long team project management tools are applicable to 30-minute synchronous DMTL activities in the classroom, e.g. CATME features?
- What parameters should be specified? e.g. number of teams, activity duration, etc.?

Theme 1D: Educational Games
- How does DMTL relate to Educational Games? e.g. attributes in common, compare/contrast?
- Which progress achieved / features in Educational Games can be most useful to apply to DMTL?
- What is the role of VR to conduct DMTL activities in the near and long term?
- Can we describe a 'best application' of Games/VR for DMTL?

Theme 1E: Assessment Mechanisms
- Team vs. Student Scoring Resolution, e.g. is there benefit in providing student-level traceability?
- Which capabilities can be feasible for automation of scoring? And mechanisms to realize those?
- What would constitute Real-time Dashboard Display content vs. static summary report content?
- How to determine correctness, time-on-task, and identification of pioneer teams automatically?
- How to annotate/organize/provide feedback on submissions?

Theme 1F: Standards & Clearinghouses
- What are preferable mechanisms and interfaces needed for effective LMS integration of DMTL?
- Definition of transportable formats: will they help to interchange activity content? and results?
- Clearinghouses for problem banks: what, where, when?
- Symposia: crosslinking sessions in which conferences? CSCL, CSCW, EDM, ASEE, AERA, etc.

Figure 6: Themes in Track 1 and their corresponding Guiding Questions.

3.4.2 Track 2: Personalizing Collaborative Learning through Analytics

The focus of Track 2 was the personalization of collaborative learning through analytics. Primary topics of Track 2 included the following:

- Utilizing offline data-mining of assessments for automated optimization of team composition and sustained back-end reporting of learning outcomes;
- Collecting and leveraging real-time observations of team member participation, dynamically identifying learners needs/ZPD, restructuring learner cohorts, and generating instructor/learning guidance on-demand; and
- Defining metrics, benchmarks, and repositories for the evaluation and interchange of worthwhile algorithms and techniques to advance analytics of effective learning teams.

Sample guiding questions for Track 2 included:

- How can student formative assessment data be used to optimize student learning teams?
- What are prototypical platforms, and key functionalities of these platforms, available to rapidly and optimally form and convene student teams?

3.4.3 Track 3: Supporting Digital Teams using Active Pedagogical Strategies

The focus of Track 3 was the exploration of mechanisms to support digital teams via active pedagogical strategies. Primary topics of Track 3 included the following:

- Defining pedagogical strategies for technology-enhanced active learning to support synchronous student team-based events;
- Underpinning the team activities within STEM classroom settings via cognitive science, including peer interactions, intrinsic/extrinsic incentivization, and lurker/lone wolf interactions; and
- Exploring andragogical/pedagogical methods leading to auto-gradable/reusable/scalable problem design, Individual/Team Readiness Assessment Tests (IRAT/TRAT), Most Valuable Peer (MVP) protocols, and actionable lesson plans.

Sample guiding questions for Track 3 included:

- What pedagogical strategies support the engagement of all learners in team-based learning?
- Which pedagogical strategies minimize challenges typically associated with team-based learning?
- Which pedagogical methods support the assessment of the contributions/achievement of individual students when utilizing team-based learning?

3.4.4 Track 4: Empowering Equitable Participation through DMTL

The focus of Track 4 was related to empowering equitable participation of diverse learners through DMTL. The scope of this track included:

- Fostering collaborative digital learning approaches that broaden participation among underserved and underrepresented populations;
- Investigating the role of socially-agnostic participation: neutral from observation (no preconceptions), and also neutral from some aspects of active projection (reduced dominance from interpersonal tone)

- Providing mechanisms to elevate retention and achievement through personalization-supporting diverse learners in collaborative settings across multiple disciplines in STEM.

Sample guiding questions for Track 4 included:

- How can DMTL support participation and achievement of underrepresented students in STEM?
- What approaches can be taken to reduce social barriers among students that may be underrepresented in the STEM population?
- What approaches can be taken to give equal opportunity to students who may have difficulty participating in team activities (e.g., due to personality, disability, etc.)?

4.0 Template-Based Participation Flow

To maintain participants' focus during the workshop, each track was divided into 4 – 6 themes (see Table 2), which were selected based on the position abstracts received. To ensure that each theme was addressed comprehensively, while also managing and focusing the track discussions, the workshop was divided into a series of one-hour breakout sessions, with each breakout session being devoted to a particular theme (on day 1). To facilitate engagement and discussion, participants are provided with a template for each theme, in which they were to identify key concepts, areas of concern, and emerging points of discussion, which would in turn, be used to populate the White Paper.

4.1 Designation of Themes

As mentioned, participants were provided with guiding questions specific to each track. This approach was mirrored regarding each theme, with discussions for each theme being driven by a series of guiding questions, which were useful in also clarifying the primary aims and scope of each theme. A sample set of guiding questions for Track 1 themes is identified in Figure 6.

4.2 Template Boilerplate

To support the overall goals of the workshop and facilitate the development of the white paper, one-page templates were provided to participants during each breakout session (see Figure 7). The focus of template use was the drafting of key aspects of the discussion surrounding each theme, particularly in response to each guiding question, which was then be used to inform the finalization of the White Paper. As a tool to support familiarity with the process and interactions for each track discussion and breakout session, the templates were identical, except for the track name and theme.

Table 2: Workshop Tracks and Themes

	Track 1	Track 2	Track 3	Track 4
Theme A	Activity Authoring	Types of Learner Data (e.g., speech, biometrics)	TPACK in DMTL	Factors of Engagement
Theme B	Student-Facing Delivery	Assessment Mechanics (analytic approaches for literally noisy data)	Engagement & Accountability	Fostering Inclusivity
Theme C	Instructor Orchestration	Challenges for Optimization of Group Learning	Team Management	Equity & Diversity
Theme D	Educational Games	Using Data to Provide Feedback	Emerging Pedagogies	Transferability & Sustainability
Theme E	Assessment Mechanisms	Enhancing Cognitive Demand and Mastery of Learning Outcomes	Faculty & Student Orientation	Possibilities of DTML

Theme 3E: Faculty and Student Orientation

- **State of the art** for this theme:
- Some **challenges** for this theme:
- **Key works** related to this theme (5 to 10 citations):
- **1-year** research objectives:
- **3-year** research objectives:
- **5-year** research objectives:

Figure 7: Sample Template used during Breakout Sessions.
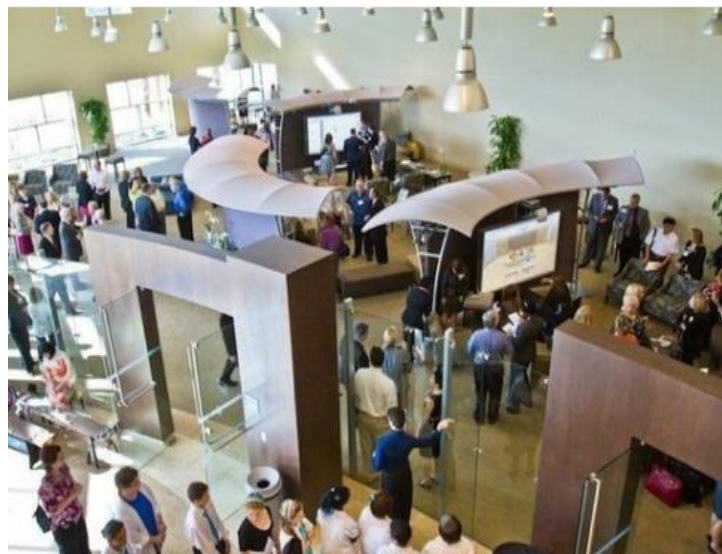
Figure 8: Collaboration facility for Breakout Sessions.

Table 3: Attendee Institutions.

- Carnegie Mellon University
- Colorado School of Mines
- Concord Consortium
- Duke University
- Embry-Riddle University
- Florida State University
- George Mason University
- Georgia State University
- Georgia Tech
- Harvard University
- Indiana University
- McGraw Hill Education
- New York Hall of Science
- New York University
- North Carolina State Univ.
- Oregon State University
- Pennsylvania State Univ.
- Pepperdine University
- Purdue University
- Rutgers University
- St. John's University
- Syracuse University
- Texas Tech University
- UCLA School of Medicine
- University at Albany
- University of Calif., Irvine
- University of Central Florida
- University of Florida
- Univ. of Hawaii West Oahu
- Univ. of Wisconsin-Madison
- University of Michigan
- UNC Charlotte
- University of North Texas
- University of Portland
- University of San Diego
- Univ. of South Carolina
- Univ. of South Florida
- University of Tampa
- Univ. of Texas at Arlington
- University of Texas at Tyler
- University of Washington
- University of Wyoming
- Virginia Tech
- Worcester Polytechnic Inst.

4.3 Breakout Session Organization

The workshop was partitioned into nine 1-hour breakout sessions (five on the first day, and an additional four on the second day), each taking place in state-of-the-art conference rooms within the Morgridge International Reading Center at the University of Central Florida (shown in Figure 8). During a breakout session, participants attended one of concurrent four sessions, corresponding to their track, with each session designed to address a specific track theme. At the beginning of each session, a shared document version of each track theme's template was shared with each participant and was to be edited collaboratively with other members of their track. To facilitate focused and constructive discussions, and to eliminate rogue and off-topic discussions (which was difficult due to the diverse and expansive expertise among track participants), a designated track leader served as a moderator and timekeeper for each breakout interval. Breakout sessions were designed to advance toward defining the aims and scope of the theme, using the theme's guiding questions as a roadmap. While these initial steps consumed a few minutes, they were useful in ensuring that the remaining time in the initial session, as well as subsequent sessions, was used productively.

At the end of the first day, the templates filled out by workshop participants were mined and served as an outline for the White Paper. On the second day, participants used their time to once again look over the templates resulting from the Day 1 breakout sessions, and used the Day 2 breakout sessions to both extend and refine ideas via an approach that has been effective in industrial settings [10]. To encourage comprehensive discussions, and to maximize the extensive and diverse expertise, participants were encouraged to switch tracks for some of the Day 2 breakout sessions. Upon finalization of the concepts and ideas for each track, track members, led by track co-chairs, began drafting the narrative of the White Paper, to be completed after the workshop ended and, subsequently, presented to NSF.

5.0 Conclusion

The DMTL Workshop was sponsored by NSF, the Helmsley Charitable Trust, McGraw Hill Education, and

UCF's College of Graduate Studies. Over 600 emails were sent in support of participant recruitment efforts. In addition, several e-mail distribution lists were used, including ASEE, CIRCL, and TBLC, each of which sent Workshop recruitment information to their members. In total, 86 participants registered from more than 40 institutions, as listed in Table 3. Participants included five panelists, four keynote speakers, nine workshop organizers, and approximately 20 local attendees from the UCF community. Approximately 50 stipends were awarded to U.S. citizens/permanent residents, including keynote speakers and numerous experts in several fields associated with DMTL. Moreover, more than 30 position abstracts and over 60 expertise profiles were received. Several DMTL-related companies and organizations attended the Workshop, including those showcasing the CATME Smarter Teamwork [11], Collabrify [9], Idea Thread Mapper (ITM) [12], and InteDashboard [13] frameworks. Lastly, the workshop brought together diverse DMTL communities, such as those who publish in venues of Computer-Supported Collaborative Learning, Computer-Supported Collaborative Work, and the International Society of Learning Sciences. The results of the Workshop were disseminated via social media outlets, a program website, and in the final version of the White Paper, which was delivered at the NSF summit on Future Digital STEM Learning Environments which was convened upon completion of the nine workshops conducted through NSF-18-017.

Acknowledgements

References

[1]   "Synthesis and Design Workshop: Digitally-Mediated Team Learning," NSF Project DRL-1825007, Retrieved from: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1825007

[2]   "Dear Colleague Letter: Principles for the Design of Digital Science, Technology, Engineering, and Mathematics (STEM) Learning Environments," NSF DCL 18-017, Retrieved from: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1825007

[3]   J. W. Lin and Y. C. Lai, "Harnessing Collaborative Annotations on Online Formative Assessments," *Journal of Educational Technology & Society,* Vol. 16, No. 1, pp. 263 - 274, 2013.

[4]   R. F. DeMara, N. Khoshavi, S. Pyle, J. Edison, R. Hartshorne, B. Chen, M. Georgiopoulos,"Redesigning Computer Engineering Gateway Courses Using a Novel Remediation Hierarchy," in *American Association for Engineering Education National Conference (ASEE-16)*, New Orleans, LA, USA, 2016.

[5]   R. F. DeMara, S. Salehi, B. Chen, and R. Hartshorne, "GLASS: Group Learning At Significant Scale via WiFi-Enabled Learner Design Teams in an ECE Flipped Classroom," in *Proceedings of American Society for Engineering Education (ASEE) Annual Conference & Exposition,* Columbus, OH, USA, June 26-30, 2017.

[6]   M. Sanders, S. Spiegel, and J. Sherer, "Moving Beyond Does Active Learning Work?" with the Engineering Learn-ing Observation Protocol (ELCOT)," in *2018 ASEE National Conference and Exposition*, Salt Lake City, UT, USA, June 24 - 27, 2018.

[7]   M. A. Kazemitabar *et al.*, "Creating instructor dashboards to foster collaborative learning in on-line medical problem-based learning situations," in *Proceedings of International Conference on Learning and Collaboration Technologies*, pp. 36-47, Las Vegas, NV, USA, July 15-20, 2016.

[8]   S. Lu, L. Lazos, and R. Lysecky, "FEAL: Fine-Grained Evaluation of Active Learning in Collaborative Learning Spaces," in *Proceedings of ASEE Annual Conference and Exposition, Conference*, Columbus, OH, USA, June 26-30, 2017.

[9]   C. Norris and E. Soloway, "The Collabrify Research Platform: A research tool for studying synchronous collaboration in the classroom," in *Proceedings of iConference 2017*, Wuhan, China, March 22-25, 2017.

[10]   L. Karas and D. H. Rhodes, "3 The Common Denominator," in *Proceedings of INCOSE International Symposium*, Vol. 9, No. 1, 1999.

[11]   Misty L. Loughry, Matthew W. Ohland, and David J. Woehr. "Assessing teamwork skills for assurance of learning using CATME team tools," *Journal of Marketing Education*, Vol. 36, No. 1, pp. 5-19, 2014.

[12]   J. Zhang, M.-H.Chen, D. Tao, Y. Sun, J. Lee, & D. Judson, D., "Fostering sustained knowledge building through metadiscourse aided by the Idea Thread Mapper. In O. Lindwall, P. Ha´kkinen, T. Koschmann, P. Tchounikine, & S. Ludvigsen (Eds.), *Exploring the Material Conditions of Learning: The Computer Supported Collaborative Learning (CSCL) Conference 2015*, Vol. 1, pp. 166–173. Gothenburg, Sweden: *International Society of the Learning Sciences*.

[13]   B. O'Dwyer, "Training the next generation in aviation with technoogy enabled team-based learning," in *Proceedings of 2018 AviAsian Conference*, Singapore, September 5, 2018.