Delivering Hands-On Experiences with STEM Technologies in Virtual Learning Environments: Professional Development for a Diverse Network of School Educators

Amari Tevell Simpson
College of Education
University of Illinois at Urbana-Champaign
Urbana, IL, USA
atsimps2@illinois.edu

Luisa-Maria Rosu
I-STEM Education Initiative
University of Illinois at Urbana-Champaign
Urbana, IL, USA
rosu@illinois.edu

Lara Hebert
Grainger College of Engineering
University of Illinois at Urbana-Champaign
Urbana, IL, USA
lhebert2@illinois.edu

Irfan S. Ahmad
Grainger College of Engineering
University of Illinois at Urbana-Champaign
Urbana, IL, USA
isahmad@illinois.edu

Meagan Pollock
National Alliance for Partnerships in Equity
Gap, PA
mpollock@napequity.org

Lynford L. Goddard
Grainger College of Engineering
University of Illinois at Urbana-Champaign
Urbana, IL, USA
lgoddard@illinois.edu

Abstract: Diversifying the STEM pipeline requires reforming school educator practices to adjust how STEM messaging and learning experiences influence diverse young people's interests and trajectory into STEM long-term. Catalyzing Inclusive STEM Experiences All Year Round (CISTEME365) is an NSF multi-pronged project designed to offer professional development and networked community for school educators to improve their knowledge and implementation of STEM experiences for their students. We worked with school educators to create and implement informal hands-on activities with STEM technologies for students to experience project-based engineering design throughout the school year. As we continue onto our program's second installment, we have adjusted our professional curricular offerings and modified our STEM club experiences to virtual-only formats. Using the experiences from the first two years, we demonstrate and discuss our current practices of making these adjustments from our leadership team. We collaboratively reflected on the experiences of leading virtual STEM clubs from our networked community of educators. This presentation highlights lessons and practices learned to ignite the

potential for postsecondary and K-12 educators to work together, displays the capacity for school educators to deliver STEM club experiences in a virtual format, and demonstrates the need to build networked communities for K-12 educators to diversify the STEM pipeline.

Keywords: COVID-19, professional development, information technologies, and information sharing

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Context of CISTEME365 Intervention

Across the United States (U.S.), lack of ethnic, racial, and gender diversity impacts many STEM fields (Crosby et al., 2003; Peckham et al., 2007; Wiswall et al., 2014; Yoder, 2016). With bachelor degree attainment in engineering as low as 22% for Black or African American, Hispanic or Latino, and American Indian or Alaska Native altogether and 21% for women, there is continued precedent for increasing the number of diverse ethnic, racial, and gender students persistence onto STEM-related majors and careers long-term (National Science Foundation, National Center for Science and Engineering Statistics, 2019). Research supports that informal STEM enrichment opportunities have improved students' attitudes, knowledge, and skills toward STEM majors and careers (Afterschool Alliance, 2011; Alexander et al., 2007; Dabney et al., 2012). Since school counselors serve as gatekeepers for informal learning opportunities in K-12 school settings, we believe it is essential to include counselors in STEM equity efforts. Previous research has shown that counselors with little knowledge about engineering fields and content knowledge differentially influence their engineering career guidance with students (Pollock, 2013). Thus, it is essential to work with counselors to discuss these high-demand, high-wage, and high-skill jobs with students to influence the participation and matriculation of women and people from less socioeconomically advantaged backgrounds onto STEM careers, specifically in the field of engineering. Because new strategies and interventions to curb these systemic barriers are important for meaningfully improving these specified groups' outcomes, our work taps on counselors to build, connect, and sustain students' learning opportunities in STEM all-year-round (Schmidt et al., 2012).

CISTEME365 Professional Development and Program Description

Catalyzing Inclusive STEM Experiences All Year Round (CISTEME365) is a multi-year, multi-pronged project strategically designed for working with school teachers, counselors and administrators in addressing informal STEM learning opportunities for K-12 students throughout the state of Illinois. In our initial planning for our CISTEME365 project, our first targeted programming component consisted of a 10-day in-person professional development summer Institute for Inclusion, Diversity, Equity, and Access (IDEA) for teams of counselors, teachers, and other relevant school stakeholders. During the summer, IDEA team members learned foundational materials for engineering content knowledge and developed action research projects (AREPs) for improving STEM-equity and developing informal STEM-enrichment clubs for their students within their school settings. The STEM-equity content and engineering-content knowledge were facilitated by nationally recognized STEM-equity and STEM-content experts, respectively. Over the first school year, IDEA teams met virtually in a network improvement community (NIC) to discuss the implementation of their AREPS and further their engineering content knowledge. Our second targeted programming component consisted of the informal STEM-enrichment club, where IDEA team members built and sustained clubs at each school site. Each club received materials to support 50 students with hands-on, technology-rich experiences during the school year. As our last targeted programming, we offered scholarships for STEM club student participants to attend immersive STEM summer camps at our home institution. IDEA teams shared this opportunity with students as well as recruited and nominated students for this summer opportunity; we were unable to offer student scholarships during our first year of programming. As an ongoing effort to sustain these relationships across the program's funding years, we continue to reach out and share resources and opportunities for IDEA teams to utilize and disseminate to students and their families.

Delivery of STEM Technologies Professional Development in Virtual Learning Environment

The rise of the global COVID-19 pandemic affected our programming beginning in March 2020. At that time, we were towards the end of the planned first year of the program with our first cohort of five schools. While COVID-19 suspended all student activities, including the STEM clubs our program initiated, we did not perform

any adjustments to our professional development delivery for our first cohort of IDEA team members because we were already programming in a virtual format for ongoing NIC sessions after the summer institute. We did, however, make significant adjustments for our second cohort of IDEA team members to adapt the delivery of hands-on activities with STEM technologies in engineering while at the same time continue to train for addressing the microaggressions in STEM instruction.

The assumption in our program activities was to emulate particular norms of interaction with and between the IDEA team members, as these norms prescribe certain behaviors once they are socially routinized in professional interactions, and with learners, they become established practices (Frese, 2015). For the professional development training, even in the VLE, we continued to encourage the participants to work through this program together and practice using their diversity to their advantage following the four agreements (Singleton & Linton, 2006):

1.1 We started with Singleton and Litton's four agreements for courageous conversations, which we adapted and revised for our session to consist of the following:

- *Stay engaged:* Staying engaged means "remaining morally, emotionally, intellectually, and socially involved in the dialogue."
- *Experience discomfort (Stretch and reflect):* This norm acknowledges that discomfort is inevitable, especially in dialogue about race, and that participants make a commitment to bring issues into the open. It is not talking about these issues that create divisiveness. The divisiveness already exists in society and our schools. It is through dialogue, even when uncomfortable, the healing and change begin.
- *Speak your truth:* This means being open about thoughts and feelings and not just saying what you think others want to hear.
- *Expect and accept nonclosure:* This agreement asks participants to "hang out in uncertainty" and not rush to quick solutions, especially concerning racial understanding, which requires ongoing dialogue.

1.2 Additionally, we invited participants to brainstorm in small groups responses to the following prompts:

- Identify successful team/group norms based on your past experience. What made the experience successful?
- Identify the behaviors attributed to these successful team/group norms

1.3 Lastly, as facilitators and IDEA team members, we next compiled and condensed these responses to generate the following list of co-created norms and behaviors for our professional development sessions:

- *Unplug!* This means to remove any devices that are not required for this session and to remain engaged.
- *Equity of voice:* This includes giving everyone a chance to speak and acknowledge each discussion that everyone can contribute. Furthermore, this also includes providing a space for others to reflect and share thoughts. Lastly, along with sharing speaking time, it is also important to actively listen to one another and not ignore each other during these sessions.
- *Support others:* This means asking for help and being helpful as much as one can. This also means that everyone will help others learn and navigate the content and VLE with patience, kindness, and respect
- *Take backs & shout outs:* This means one can share significant applicable, helpful takeaway information to one's respective school site, and when in this space, folks can share affirmations for one another. The group shared that it is important to take the time to acknowledge one another's achievements and accomplishments during the professional development sessions.
- *Open headspace:* This means that it is important to provide a space where everyone's ideas are accounted for, and within this space, it is vital to assume well intentions of each other. Lastly, it is essential to embody a growth mindset, where everyone is capable of furthering one's understanding of complex, demanding tasks or content.
- *Stewardship of norms:* Stewarding of norms means that it is essential to continue to work together to establish and maintain group norms and goals.

For the NIC, during the second year, we continued to advance the premises (as norms and values) for initiating the networked community from the previous year, respectively:

2.1 This is *an equal opportunity learning community*.

2.2 We *value the diversity* represented by the teacher, counselor, and student participants of this program.

2.3 *Promoting diversity and a culture of inclusiveness* will be the primary sources of ideas, perspectives, and learning.

For supporting training for the implementation of the STEM curriculum/and learning with STEM technologies in the after-school clubs, we combined the lessons learned during the first year, in-person professional development with the anticipated challenges of how to deliver hands-on engineering experiences in a virtual learning environment (VLE):

3.1 *Give early access to the materials regarding engineering and technology innovation.* The program delivered materials by mail for the hands-on activities to the second cohort participating schools. Simultaneously, it required IDEA teams to systematically read directions and view video materials to be prepared for the synchronous hands-on interaction.

3.2 *Integrate hands-on activities with online assignments and add virtual office hours to respond immediately to issues in STEM clubs implementation.* The time to respond to all requests for clarifications was limited during the institute day. During the STEM clubs' implementation, IDEA team members realized they would have liked to be able to ask for more technical guidance. Office hours were the immediate response, however, we worked with participants who had as well a limited amount of time. We had to learn what to cut off and what to simplify, what was essential for understanding and what could be left to participants' innovation/adaptation to their own school context.

3.3 *Reflect on learning new technical content about engineering and electrical engineering.* Learning new technical content about engineering and electrical engineering in K-12 is intrinsically an extracurricular activity. When the program was delivered in person, participants had the opportunity to visit research and teaching labs, interact with experts and professionals in the field, and place the new technical content within its own context. It was not the case in the VLE.

3.4 *Establish a bridge between the virtual content delivery for the engineering projects and the training addressing microaggressions in STEM instruction.* Initially the program had separated the delivery of learning with STEM technologies from the training how to respond to microaggressions in STEM education. The challenge for our program in particular was that we tried to have counselors learning about and working with STEM technologies and teachers/curriculum coordinators acquiring skills to identify and address microaggressions. This was demanding even when in person and the tendency of the participants to remain in their expertise silos, especially under the pressure of COVID-19 challenges, had to be constantly discussed. Originally, the counselors were unfamiliar with engineering as a component of science teaching and expressed a lack of knowledge of engineering.

COVID Changes and Information Technology Strategies

The changes in the approach of the program's components and pillars between year 1 and year 2 are illustrated (Tab. 1):

Year 1	Year 2
Institute: 10-day, in-person during summer (5 days focused on STEM equity and the remaining 5 days focused on various STEM technical activities)	Institute: 5-day, virtual synchronous over two weeks in summer, followed by 6 full-day, once per month until March 2021. Each with half-day STEM equity and half-day STEM technical activities.
NIC: 1 hour after school day, once per month	NIC: 1 hour embedded in full-day Institute sessions
AREP: Introduced at end of Institute	AREP: Introduced after STEM Clubs implemented in Fall 2020
STEM clubs: envisioned as separated/additional to existent in person STEM after school initiatives	STEM clubs: envisioned as merging with existent after-school initiatives in virtual environment

Table 1. Year 1 to Year 2 CISTEME365 Programming Differences

To be able make the transfer of norms and enact practices, we considered a variety of information technology strategies to support the conversion of the PD institute from learning with in-person instruction to a virtual experience. Within a typical day of our virtual professional development programming, we use Zoom meeting platform for synchronous instruction, integrating other information-sharing sites (e.g., Google Jamboard, Google Docs suite, etc.). The Moodle open-source platform provided a single-stop location for ongoing access to all resources, tools, platform access, and asynchronous interactions (e.g. discussion forums, Flipgrid, etc.) in between scheduled professional development sessions. The schedule for a typical professional day during the institute and the use of information technology strategies looked like (Tab. 2):

Time	Instructor	Topic	Information Technology Strategy
8:30 AM	Amari Simpson and Participating Schools	Intro / Morning Reflections; Warm Up with Engineering Design or school presentations	Google Jamboard and Google Slides
9:00 AM	Dr. Lara Hebert	Networked Improvement Community	Google Slides or Jamboard; Zoom Breakout rooms
10:00 AM	Dr. Meagan Pollock	Culture	Google Slides; Moodle Assignment discussion
11:00 AM	Dr. Meagan Pollock	Positionality & Intersectionality	Google Slides; Zoom chat/Breakout rooms
12:00 PM	LUNCH		
1:00 PM	Dr. Lynford Goddard	Soldering	Pre-recorded videos, Zoom chat; 2nd camera for overhead view of demonstrations
2:00 PM	Dr. Lynford Goddard	Testing the Radio Phone Circuit	Pre-recorded videos, Zoom chat
3:00 PM	DISMISSAL/Clarification and Reflections		

Table 2. Sample Schedule during Institute including utilized Information Technology Strategies.

The Importance of Hands-on Learning in STEM

The ability of learners to go beyond facts and to think critically, while at the same time enjoying and valuing the learning process, is fundamental to effective science and engineering instruction. Making engineering instruction more effective can promote greater equity and hands-on experiences, supporting a conceptual change approach to engineering instruction that explicitly activates learners' pre-existing ideas and misconceptions and helps them construct more effective understandings. Before COVID-19, the instruction in VLE was mostly associated with individual learning and direct teaching. The advantages and disadvantages of including lab and hands-on training in an online environment were debated with some studies arguing that there was not much of an advantage when learning a hands-on procedure online, compared to just having the procedure explained. The COVID-19 situation forced many education initiatives to re-envision the challenge of hands-on and lab activities in VLE. For educators, they face this situation by both delivering and learning at the same time.

Hands-On Experiences in CISTEME365 Virtual Learning Environment

CISTEME365 hypothesized that experiences with cutting-edge technology must exist all year-round to effect significant improvement. Thus, the fundamental project goal is to broaden access and participation in STEM for middle and high school students to participate in sustained, intensive, hands-on STEM learning experiences that build technical knowledge & ability, and that offer insight into different STEM majors & careers. Consequently, it was extremely important to convert the delivery of hands-on experiences into the VLE as well as to try to understand how the delivery of instruction with STEM technologies affects the norms and practices employed initially in the face-to-face implementation.

Our program included a rich agenda of engineering activities with a variety of hands-on experiences: from the development of an online simulator for learners to test circuit design prior to construction, to procedural directions for performing soldering. Participants also started preparing an action research project and presenting their initial work to their peers. Immediately, we wondered how the delivery of the hands-on learning would change in the VLE?

Analyzing the ways online learners have engaged in scientific processes as they conducted relevant and real‑world CISTEME365 activities from their own locations. We re-evaluated how the norms and practices supporting the pillars of our program have been transferred during this process of going virtual for the CISTEME365 and considered those related to hands-on experiences with STEM technologies more closely:

1. In what ways did the change in the nature of the learning environment (from face to face to virtual) require a change of the employed norms (potential practices)?

2. Did the hands-on training activities, originally developed as having value only when being delivered in-person need reconceptualization for a virtual environment?

Discussion

Given the challenges COVID-19 brought to our program, we examined our experiences in three critical areas: 1) selection of appropriate and engaging online resources for IDEA team members, 2) adaptability and flexibility when delivering virtual professional development content on STEM-equity and engineering topics and engineering design, and 3) effectiveness in meeting the diverse information-literacy and information-processing of school educators from various demographic backgrounds.

The COVID-19 pandemic replaced participant immediacy in the physical space with their virtual presence (Kuznetsova et al., 2020). Because of this, the juxtaposition of various virtual contexts (the school context, program context, and home context) affected the delivery of the CISTEME365 program's norms and ability to enact face-to-face practices in VLE. In the VLE, we realized that the face-to-face immediacy that normally drives us was impossible due to the COVID-19 circumstances. This shift in content delivery and communication to VLE affected the hands-on experiences and shared learning related to in-person, hands-on, and responding directly to emerging, immediate learner needs:

> *The ability for the participants to talk to one another is vastly diminished when virtual. In person, you can have everyone in a room and 10 parallel conversations going on. In the virtual format, a lot of that is lost. So, there isn't the bonding of participants across schools or within schools that we had when we were in-person. So, setting aside time for the teams to talk even within teams or between teams [...] is important. - Goddard*

Teacher immediacy has been considered a foundation for learner's motivation and engagement in particular for underrepresented groups in STEM education. Practices like "respond immediately to issues in the implementation of STEM clubs" had to be reevaluated. The new question we had was how to reformulate certain practices in such a way that the diminished instructor/teacher immediacy could still sustain and increase student agency, and help them become active and independent learning agents. We learned that this is tightly related with the nature of participation in the activity and redefine program professional relationships as participatory relationships.

> *If anyone would agree just to have a little time together as a team to plan more. I think we did have one or two days during summer [...] training that we had some time to talk about how we would roll it out. But I think in the last couple, we haven't had time to just, even if it's like 10 minutes to chat with our team about [...] [the] next step[s]. [...] I'm hoping to work with the (teacher's name) and hopefully pick a day where I could start incorporating some of the, the [...] emotional concepts that we've been learning. - IDEA Team Counselor*

Though our CISTEME365 norms work began with Singleton and Litton's (2006) four agreements for courageous conversations, both quotes point to the need for added norms to be considered when planning for VLE for teaching and learning. Specifically, for VLE facilitators, there is a significant need for learners in VLE to interact and discuss with one another about shared learning content.

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Acknowledgements

This research was supported by a grant from the National Science Foundation under Grant No. 1850398. The data presented, the statements made, and the views expressed are solely the responsibility of the authors.