Preparing Kenyan Teachers for Online Delivery: Applicable Lessons from a Six-Week US STEM-Teachers' Professional Development During the Covid-19 Pandemic.

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Abstract

This article reflects on experiences garnered from a six-week summer Zoom-based synchronous Research Experience for Teachers' (RET), for professional development program, on data science and its application to cybersecurity, which took place at Texas Tech University during the COVID-19 pandemic. An autobiographic approach to explore how middle and high school STEM teachers experienced transformative learning during the program was used. The process-oriented framework to understand how teachers experienced online teaching and learning was utilized. This process-oriented framework outlines the skills and competencies for online teaching that instructors should embrace to realize transformative online learning. The study involved nine STEM teachers—six men and three women. Virtual observations, and teachers' reflection journals to document learning behavior were applied, which revealed that social interaction, collaboration, communication, can occur effectively in an online learning environment.

Keywords: Cybersecurity, Data science, COVID-19, Learner-centered, STEM teachers, Virtual learning, Technology integration.

INTRODUCTION

COVID-19 pandemic had a serious global effect on most educational systems after more than 190 countries implemented nationwide school closures, affecting over 1.7 billion students (Mustafa, 2020). The global decision to close schools was seen as an effort to curb the spread of COVID-19 through non-pharmaceutical interventions and preventive measures, such as social-distancing and self-isolation. In response to school closures, universities recommended the use of distance learning programs and open educational applications and platforms that teachers could use to reach learners remotely and limit any academic disruption (Ngumbi, 2020). As a result, many countries ensured that teachers were able to create virtual classrooms where they could interact directly with students (World Bank, 2020). However, lack of access to technology or good internet connectivity has continued to be an obstacle to learning in many countries (Mustafa, 2020). Therefore, for Kenyan schools to reach learners remotely, it will depend on the successful integration of the Kenya laptop initiative into the classroom instruction (Mutua, 2013; Waweru & Kihara, 2013). For this reason, there is a dire need to explore how "ICT can effectively be embedded in instructional reform" in Kenya (Piper et al., 2015, p. 13).

The status of ICT integration to school programs in Kenya

Kenya is among other sub-Saharan countries in Africa that are at the forefront of ensuring that ICT is used to improve educational outcomes (Piper et al., 2015). Nonetheless, Nchunge et al. (2012) pointed out that schools in Kenya have failed to adopt ICT despite its significance in service delivery in education. The limited adoption of ICT in schools can be attributed to teachers' negative attitudes towards technology due to a lack of skills and pedagogical teacher training (Ngololo et al., 2012; Tondeur, 2019). Further, Piper et al. (2015) also attributed ICT's slow adoption to Kenya's rigid traditional education system and restrictive curriculum. Therefore, Tondeur (2019) stresses the significance of teachers' professional development in technology integration to improve teachers' professional knowledge in the context of their work.

Conceptual model: Process-oriented framework for effective online teaching

Abdous (2011) outlined specific activities that are structured around three sequential non-linear/iterative phases: *before* (preparation, planning, and design), *during* (facilitation, interaction, and feedback), and *after* (reflection and lessons learned), which follow the unfolding of the online teaching experience.

The preparation, planning, and design phase require instructors to participate in professional development to acquire online teaching fundamentals and pedagogical skills. The instructors are expected to reflect on the transition from in-person teaching and learning to online teaching environments focusing on similarities and differences between the two environments. Abdous (2011) considers an instructor's active participation in this stage instrumental to the overall preparedness and effectiveness of one's teaching online. An instructor "integrates effective learning activities that are aligned with learning objectives, while remaining mindful of various technical and logistical constraints" (Abdous, 2011, p. 66).

During the actual teaching, Abdous considers facilitation, interaction, and feedback as key activities in the online classroom. It is the responsibility of the instructor to welcome learners to the learning environment and pronounce with clarity the instructor's expectations, weekly time commitment, and deadlines to submit assignments. This phase entails the instructor to develop a positive rapport and assist learners to take responsibility for their learning. Similarly, the instructor should develop a sense of learning community among participants to cultivate meaningful and in-depth interaction through focused, and relevant open discussions. At this stage, regular and relevant students' feedback is key data to assess the effectiveness of the course content and activities (Abdous, 2011).

The reflection phase is a self-improvement therapy for the instructor. Abdous (2011) encourages instructors to keep reflective journals on their experiences. The data from these journals should include lessons learned to help improve the course. Using the process-oriented framework, this study focused on the pedagogical practices that would enable teachers to create a conducive online classroom.

Skills and effective pedagogies for online teaching and learning

The emergence and use of technology in learning institutions have expanded classroom boundaries and reshaped teaching and learning in schools (Barber et al., 2013). To keep in line with these changes, "new teaching pedagogies, learning skills, and assessment methods have emerged" (Albrahim, 2020, p. 9). Online learning is founded on constructivist theories that advocate for

collaboration between instructors and students for transformative learning (Budhai & Williams, 2016; Ruarte, 2019). Thus, a successful learner-centered approach to online teaching requires teachers to adopt pedagogical practices compatible with the integration of technology in the classroom to effectively communicate with learners (Albrahim, 2020). The instructors endeavor to ensure students communicate, interact, collaborate, and are engaged throughout the online sessions (Palloff & Pratt, 2011). Albrahim (2020) identified six categories of teaching skills and competencies that instructors should have to be successful in online teaching: a) pedagogical skills, b) content skills, c) design skills, d) technological skills, e) management and institutional skills, and f) social and communication skills. The six categories of teaching skills can be compressed into four effective pedagogies: teaching, social, cognitive, and technical/managerial presence (Ruarte, 2019).

Teaching presence: This refers to the level of engagement and participation of an instructor in the strategic design and outcomes of a course. The teacher should be able to link the subject and content to real-life experiences (Abdous, 2011). Albrahim (2020) argues that teachers should understand and apply strategies related to the learner-centered approach and collaborative learning. Teachers should design course materials, instructional strategies, provide guidance and support that would facilitate student interaction, collaboration, and teamwork. Teachers should show enthusiasm, encourage a student's self-assessment and reflection.

Social presence: This focuses on building friendly and interactive online classrooms. Active communication and social presence are vital to engaging online learners. Pelz (2010) encourages instructors to acquire skills in developing engaging course content to facilitate students to develop cohesive relationships. Adebisi and Oyeleke (2018) advocate for instructors to aim at encouraging collaboration and interactivity among the learners. Social presence has to do with the socio relational aspects of the online classroom and the connectivity and encouragement of the instructors. Instructors are responsible for this social engagement through the use of course activities and the intentional encouragement of a cohesive environment.

Cognitive presence: This involves designing a strategic learning environment that is conducive to meaningful learning. Online instructors should be able to develop rich discussion questions and help students to connect factual, conceptual, and theoretical content (Pelz, 2010). The entire course content should carefully be assessed to ensure it activates cognitive processes and deep learning (Ruarte, 2019). Instructors should encourage the use of discussion questions to promote deeper level thinking and meaningful learning. Instructors should be responsible for the cognitive processes of students through the careful formulation of questions.

Technical managerial presence: Technical/managerial presence involves ownership of the course design and content and the course outcomes. Online instructors should be required to have technological literacy skills to enable them to access several technological resources and tools relevant to an online learning environment. The instructor should be able to establish rules for participation, time management, sending and receiving feedback, and classroom communication (Albrahim, 2020; Ruarte, 2019). Adebisi and Oyeleke (2018) consider technology and the strategic management key to the instructor’s ownership of the online learning process.

METHODOLOGY

Autobiographical inquiry

Writing autobiographically connects the private (we) with the public (other) and thus becomes an important tool in our research. It allows us to slow down, look back and investigate, reveal, and express the lived experiences using our voice. Pinar (1995) argues that autobiography, as a discursive practice, vividly reflects a person's lived experiences to build on a complex web of different relationships and modalities. As a result, researchers found that "evocative genres of writing are appropriate methodological and pedagogical tools for examining lived experiences of individuals" (Park, 2013, p.8). The autobiographical approach permitted the first author to reflect on his first-hand experience, coping with COVID-19 normal and how it helped him reflect on its impact on schools closing globally. It was a two-step process that entailed reflecting "on my past moments that led to the awakening of my consciousness to construct the meaning of my lived experiences." The second step involved the presentation of these events and their meanings as they currently appeared to us. Thus, we use an autobiographical approach to evoke and narrate vividly our virtual interactions with nine STEM teachers during the six-week RET professional development program and examine the emerging patterns to establish interventions and plans of action, and make conclusions.

Context of the study

The study was conducted during a six-week Research Experience for Teachers (RET) professional development at Texas Tech University during the summer of 2020 to explore the learning experiences of grades 6-12 STEM teachers in data science and cybersecurity. Following COVID-19 pandemic preventive measures, such as social-distancing and self-isolation (Mustafa, 2020; Ngumbi, 2020), professional development was conducted online. Interdisciplinary faculty and teachers interacted using a synchronous Zoom platform. For the first two weeks, teachers interacted with Computer Science (CS) instructors for two hours daily (10:00 a.m. to noon) and learned data science and cybersecurity concepts. They then engaged in one-hour (1.00 p.m. to 2:00 p.m.) reflection session with Curriculum and Instruction (C&I) faculty. Thereafter, teachers interacted for two hours (2:00 p.m. to 4:00 p.m.) in small groups with Computer Science graduate students in practice exercises reinforcing the concepts taught in the morning in a lab environment. As the program progressed, teachers worked with C&I faculty on unit and lesson planning.

There were nine high school teachers (three women and six men) who taught various STEM disciplines in 6-12th grade at schools in the West Texas region. Teachers were recruited through a rigorous application process where the recruiters considered the applicants' leadership skills, STEM background, ability to integrate the new data science and cybersecurity skills in their teaching subjects, and collegiality with their peers**.**

Data sources and analysis

During the six weeks of the RET online professional development program, teachers were encouraged to reflect on their learning experiences. They documented their reflections in weekly journals based on prompts. We recorded synchronous interactions between faculty and teachers, across teachers, and between teachers and computer science doctoral students via Zoom audio. We later analyzed data from our observation journals, teachers' reflection journals, and products

(collaborative group research projects, PowerPoint presentations of research projects, and unit and lesson plans) to assess the teachers' learning experiences.

We coded and analyzed collected data using computer software for data analysis – NVivo 12 – to find out if teachers' transformation occurred. We used Initial, In vivo, Process, and Causation coding to extract "ongoing action/interaction/emotion taken in response to situations" (Corbin & Strauss, 2008, p. 96; Saldana, 2013) from participants' data.

RESULTS

In analyzing data, the following themes emerged: a) technology management, b) linking the content to real-life experiences, c) conducive and interactive learning environment, d) teamwork, and e) transformation.

Technology management: We prepared in advance to deal with technological issues as we understand technology is a medium of human expression and it affects human behavior and patterns of thinking (Abdous, 2011). The interdisciplinary team ensured that all its members were conversant with the Zoom online platform that was used before our first classroom interaction. The Principal Investigator (PI) emailed a Zoom link inviting all participants to the first orientation meeting. During this meeting, they practiced sharing screens, using Zoom breakaway rooms, time management, and giving feedback. This prepared the team to handle and provide help to any technological shortcomings during the six-week RET online program. The PI also ensured that support was available to anyone who experienced technological problems. For example, on the first day we recorded:

> The following issues were visible during the first Zoom session. Some participants faced challenges connecting to Zoom. Some participants had no prior experience using Zoom in the classroom like set up. Two teachers had an issue with their passwords allocated to join the Zoom meeting. However, they were assisted and joined a few minutes later. (June 8)

Another visible challenge documented on the first day was social interaction. We observed a disconnect between face-to-face classroom and Zoom sessions. One observer wrote "First, social interaction was a bit abstract. Consequently, it was a bit challenging to create a conducive learning environment. Awkward silence! It is difficult to tell who is there participating, especially when one has joined the session using audio and not video" (June 8).

The instructors overcame the social interaction and learning environment challenges by first acknowledging the significance of a synchronous Zoom session, and initializing an ice-breaking session. Observer 3 recorded:

> First, the Zoom host made the participants aware of the importance of accommodating technology as a substitute for a face-to-face classroom. The argument was that Zoom has helped bring on board all the RET participants in the comfort of their homes without fear of contracting the COVID-19 Virus. Second, the interdisciplinary faculty was in regular contact, either on phone or through Zoom on ensuring those who had issues with using Zoom were assisted and never left out (isolated from the others). (Observation notes, June 8)

During the ice-breaking session, C&I faculty informed participants that they were to be put into three Zoom breakaway groups for 15 minutes and were asked to participate in activities that encouraged social interaction. The following was recorded:

> Every participant got a chance to speak and engage other members in a discussion. The initially dull faces were now brilliant. Time management was tested as the timer for the breakaway room was active. During the *Second breakaway 15 minutes*, the second group had more time to discuss freely. There was minimal tension and voluntary participation was notable. In the *Third breakaway 15 minutes*, the members could refer to each other by name. The session had more humor and chit-chat. (Observation notes, June 8)

Thereafter, C&I instructors engaged participants in reflections on what transpired in their breakaway rooms. One teacher noted that "sitting for two hours made him identify with what students go through in a normal classroom situation" (Observer 2).

As the program progressed, teachers got conversant with the online learning environment and exhibited technology management skills. For example, they interacted freely during their group discussions, and were able to share their computer screens during the individual final presentation of unit and lesson planning. It was evident that all teachers experienced transformative learning through constructive collaboration between instructors and students.

Linking content to real-life experiences: During our RET professional development program, we engaged teachers in supportive, instructional focused, collaborative, and inquiry-based learning activities. The overall objective was to create a research-rich learning environment with the expectation that teachers would adopt and transfer their learning experiences to their middle and high school STEM curriculum units. By so doing, they would cultivate critical and computational thinking skills in grades 6-12 students to develop cybersecurity talents. This was in line with Pelz's (2010) advocacy for creating content that reflects real-life situations and creating a conducive learning environment that would cultivate cognitive development in learners. For example, CS faculty engaged teachers in learning R-programming concepts so that they can apply the knowledge in data mining and modeling to solve real-life data science and cybersecurity problems. As one teacher wrote in her journal:

> Like yesterday, however, I am still most interested in discovering how to use these data science concepts in cybersecurity applications. Since I will be teaching a cybersecurity class in the fall, I am most concerned with the relevance to that field of study. I am already somewhat familiar with data science concepts, so the only new thing to me at this point is implementing those concepts in R. I am still clueless about using data science in cybersecurity. (June 25)

It emerged that the teachers adopted the content on data science and cybersecurity and were prepared to transfer it into the K-12 curriculum. This was evident in their final research projects and lesson planning.

Conducive learning environment: We ensured that the participants were involved in a learning environment conducive to meaningful learning. Teachers were engaged in learning activities, discussion questions, and received help from instructors to connect the abstract R-programming concepts to data analysis and application in cybersecurity group projects. For example, regarding teaching approach, one teacher recorded:

> I thought his [CS professor] approach to teaching this topic was effective. I would teach it much the same way. He started by showing us an application of neural networks: face recognition. It sparked my interest before we even got started. (June 11)

This sentiment was similarly expressed by another teacher who reported about the interactive learning activities:

> We also learned about some of the reasons for having missing data and how you can best replace missing data if needed. We then looked at normalizing data, which was the main focus of the lesson, using different approaches like min-max normalization, Z-score standardization, and decimal scaling. The CS professor talked us through examples of these different types of methods along with showing us how to look at and try to eliminate skewness of data. At the end of the lesson, we looked at different types of sampling and then saw her go through several code examples in RStudio where these concepts were demonstrated using R programming. (July 8)

We also observed that CS professors posed questions, and assigned tasks to teachers encouraging them to participate in the learning process. The conducive online learning environment enabled the teachers to apply the acquired knowledge in data science into their lesson and unit plans on integrating data science and cybersecurity concepts into their curriculum.

Teamwork: One of the key goals of the RET program was to engage teachers in a group research project that would reflect their learning transformation during the six weeks of professional development. The instructors developed engaging course content that facilitated cohesive relationships among learners. As one teacher noted:

> Two minds are better than one. There is no right way to do anything in R, so having more than one of us working on the same thing is bound to produce the most efficient response. Plus, I'm sure we all want to get it done and get it in the best way possible. (June 28)

The idea of teamwork was also expressed by a teacher who shared in her journal that "To work as a team in a virtual environment means that everyone involved has to pull their weight. It is even more important than during a face-to-face project that everyone is personally accountable for his/her work" (July 8).

During the last week of professional development, teachers presented their group research projects reflecting on the effect of collaborative learning. This was evident through the independent feedback captured in the *Group Project Feedback Forms.* For example, in the group working on *Intrusion Detection,* the project scored 25 out of 25 points. A CS professor remarked on the collaborative project, "I was [really] impressed with how much you were able to get done from the last presentation. I found the Boruta function [really] useful and important and wish we could have used it on our project! " (July 17). A similar assessment was registered by the group presenting on *Phishing with a URL Identification* project. A CS professor noted, "Your extension is amazing! I hope that you get to pursue it even further!" (July, 17).

Teachers transformation: One of the main goals of the RET program was to enable teachers to integrate new data science skills in designing a research project to solve cybersecurity-related threats. At the beginning of the project, some teachers were skeptical of their success in the program as one wrote:

> I am brand new to cybersecurity as it is and, at this point, I am not even familiar with the curriculum, much less how I will be able to integrate data analysis into it. Also, I am

> wondering if data analysis concepts could be integrated into a computer science class as well? (June, 9)

However, as the training progressed, there was evidence of transformation learning as the three groups of teachers collaboratively contributed to the development and presentation of their research projects. For example, one group collaborated and developed a project on how URL attributes could be used to help identify phishing sites. The group explained how the length, date, and naming of a URL link can be used to detect a phishing URL. The second group developed a project on intrusion detection. The members examined how R-programming can be used to design a model that would detect a pattern of codes that would detect intrusion.

It was amazing to see how the last group transformed from their initial stuckness status as evidenced by one of its members who remarked, "Perhaps I have missed something, but it doesn't feel like we have discussed anything about cybersecurity at all. I'm not entirely sure that I see the connection between what we have done so far and how it is related to cybersecurity. I'm eager to find that connection" (June 22).

Another member of the group wrote, "I'm curious about the applications of text similarity and sentiment analysis to predict patterns of behavior … I will admit that I still consider myself to be a novice at code-writing, but the applications of this technology seem endless" (June, 25). However, they were successful as they developed and presented a project on detecting spam content. They analyzed tweets using different online sentiment analysis dictionaries to explain whether COVID-19 data was a fact or rumor.

DISCUSSION

In this study, we observed how educators developed new knowledge of online teaching skills to enhance transformative learning. We identified teaching, social, cognitive, and technical/managerial presence that teachers needed to achieve to learn cybersecurity concepts during the online RET program. The findings of the study evidenced teachers' ability to link the content with real-life experiences, the existence of a conducive and interactive learning environment, teamwork, and technology management that helped them experience transformative learning. The findings were in line with Abdous (2011) process-oriented framework and Albrahim (2020) teaching skills and competencies for successful online teaching. Our findings thus have added to the existing knowledge in STEM teachers' transformative online teaching and learning. These findings further can inform both Computer Science and teacher educators on the importance of ensuring that teachers communicate, interact, collaborate, engage during the online professional development sessions (Palloff & Pratt, 2011) for transformative learning. Finally, the findings on teachers' ability to collaboratively integrate the new knowledge after acquiring the language of cybersecurity can inform the instructors on how to improve cybersecurity teaching methods to create a conducive online teaching and learning environment.

Nonetheless, this study had its limitations that might have influenced the findings. First, the use of convenience sampling was based on the availability of the participant for professional development during summer. Another limitation was the confinement of our teachers to their homes due to COVID-19 pandemic preventive measures such as social-distancing and self-isolation (Ngumbi, 2020; Mustafa, 2020). As a result, our study used a sample size of nine teachers to enable us to make online observations to document the participants' learning behaviors. Another limitation was the time of the study. We observed that the six-weeks were a short time and both

the educators and the teachers got overwhelmed by data science and cybersecurity course content. We endured the limitations and we are contented that our study provides valuable insights into the online teaching and learning of data science and cybersecurity to high school STEM teachers.

Practical implications for online teachers

Based on this study, it was evident that the interdisciplinary faculty had adequately prepared course content for the six-week RET program. Abdous' (2011) process-oriented framework advocates for an instructor's preparedness for a far-reaching impact on online teaching delivery. We recognized the importance of adequate preparation for a successful online classroom that we spent adequate time to prepare for relevant and effective course materials. The preparation also led us to adopt pedagogical practices that were compatible with the integration of technology in our virtual classroom to effectively communicate with learners (Albrahim, 2020). The teachers were engaged in learning activities that transformed their knowledge in data science and cybersecurity and its integration in the K-12 curriculum. At the end of the six-weeks RET program, it was evident that adequate and regular professional development and ongoing technical support were critical for effective online teaching and learning experience. There is a need to regularly update the content based on daily reflections to ensure that students' needs are taken into account. The interdisciplinary faculty reflected on teachers' feedback to improve on training. The regular reflections were in line with Abdous' (2011) third phase on a process-oriented framework that encourages instructors to reflect on their online teaching for purposes of improvement. To boost interactive and collaborative learning, teachers should research and prepare course content and learning activities that solve real-life problems as evidenced in the RET program. Teachers were engaged in collaborative group projects that were intended to solve cybersecurity issues. In a nutshell, the quality of course preparation determines the quality of learning for the students.

Pelz (2010) and Ruarte (2019) encourage online instructors to initiate debates and questions that activate cognitive processes and deep learning. We understood that constant communication through timely feedback was a key concept in developing proactive online teaching. We also recognized the importance of students' orientation on the interactive virtual environment and regular support, based on their regular and systematic feedback. Thus, the interdisciplinary faculty used daily classroom discussions that created a conducive learning environment and promoted students' cognitive growth. The teachers' transformation was evident in asking questions, engagement in collaborative group work, and integrating their cybersecurity knowledge in their final group projects and lesson plans.

The use of Abdous (2011) process-oriented framework approach helped us understand the pedagogical skills that are effective for online teaching and learning for high school STEM teachers. We were able to identify four effective pedagogies or teaching skills that teachers need to learn during an online professional development. Using the process-oriented framework, we were able to make meaning of the teachers' reflection journals and observation data that we had collected. The process-oriented framework was instrumental in informing us of the key pedagogies related to teaching cybersecurity and computer science online. Consequently, the same framework can be applied in studying other groups of online teachers in other regions of the world.

Online teaching lessons for Kenyan teachers

The successful six weeks RET online professional program for STEM high school teachers offers numerous lessons for Kenyan teachers. Technological literacy skills are instrumental in accessing

technological resources relevant to an online teaching and learning environment. One reason why ICT integration is limited in Kenyan schools is due to teachers' negative attitude towards technology since they lack ICT skills and online pedagogical skills (Ngololo et al., 2012; Tondeur, 2019). To overcome this negative attitude, Kenyan teachers must be willing to participate in professional development that will improve their technology management skills. There is a need to develop an intrinsic motivation to embrace technological literacy. For example, the nine teachers in our study volunteered to participate in a six-week summer intensive professional development on technology integration in their curriculum.

Transformative learning is dependent on the teacher's ability to create course content that engages students in solving real-life experiences. Thus, teachers should understand and strategize on the application of the learner-centered approach and collaborative learning. The success of online classroom teaching and learning is dependent on the quality of prior preparation to ensure teachers have adequate course content, availability and accessible technology for learners, and classroom communication. The course and instructional materials should be designed in a way to guide and facilitate students' interaction, collaboration, and teamwork. Student's feedback is also key to improving online teaching and can be sustained through a friendly and interactive virtual classroom. The teachers in this study were successful because program instructors developed interactive and reflective online sessions. Furthermore, teachers were orientated to a virtual social interaction to encourage teamwork. The effect of social interaction was manifested during the teachers' collaborative projects. Therefore, Kenyan teachers could embrace a collaborative approach in content design, classroom activities, and classroom communication to enhance learning.

CONCLUSION

The preeminence of technology use in classroom learning together with the rise of learners in cybersecurity, call for curriculum developers and educators to use different lenses to address learners' transformation. One ideal approach to transformative learning in high school cybersecurity literacy is a process-oriented framework for effective online teaching and learning. Our study contributes to the existing knowledge of online pedagogical skills and literature in computer security literacy. Through this study, we have presented the process-oriented framework concepts and their application in online cybersecurity professional development with high school teachers. The study documented five themes related to the learner-centered online teaching and learning approach evident of teachers' transformative learning in data science and cybersecurity. The study evidenced the pedagogical practices that online instructors should embrace to be able to integrate technology in the classroom for effective communication with learners for transformative learning. There was evidence that teachers and instructors collaborated to overcome challenges teachers experienced during professional development. Constructive theorists advocate for collaboration in online teaching and learning for transformative learning. Thus, our findings are a resource to curriculum stakeholders and computer science pedagogy who intend to explore online teaching concepts to support transformative learning.

Despite the COVID-19 pandemic that led to the partial lockdown of our university, we were able to conduct the 2020 summer RET professional development program successfully. There were numerous measures that the interdisciplinary faculty put in place to ensure that the nine teachers did not miss their training. First, there was adequate preparation for the professional development, where the interdisciplinary faculty collaborated to produce course materials for the

six weeks. The PI also ensured that all teachers were informed during the recruitment process that the training would be in a virtual environment. Second, the challenge of technology was resolved where all participating teachers were provided with a new portable laptop and required to have internet access to enable their mobility. This enabled them to work from the comfort of their homes. Third, all the participants attended a one-day orientation on technology management to embrace a virtual classroom environment. As the training progressed, participants were encouraged to participate in group discussions, ask questions, and keep a daily journal reflecting on the lessons they learned during the data science and cybersecurity classes. The collaboration between the interdisciplinary faculty and the teachers encouraged transformative learning during the six weeks of online training.

We recommend further research that would explore teachers' transformation using a larger sample size with limited resources. The challenges we experienced in identifying the key concepts in a process-oriented framework that identifies key pedagogical competencies and transformation can offer insights to researchers and scholars interested in data science and cybersecurity. More knowledge is needed in improving technological and pedagogical approaches for online delivery in under-resourced environments.

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