Designing a Creative Cybersecurity Microcredential for Educators: Challenges and Successes of K-12 Teacher Professional Development

Dr. Bekir Mugayitoglu, University of Wyoming

Bekir Mugayitoglu received his doctorate in Instructional Technology and Leadership from Duquesne University's School of Education in 2016. His research investigated the factors that influence pre-service teachers' attitudes about the importance of computational thinking and methods of teaching computational thinking to prepare students for computer programming. He worked for Carnegie Mellon University's Robotics Academy as a content developer of immersive video games for computational thinking, robotics, and STEM-based investigations. Dr. Mugayitoglu has also taught programming languages such as Python, Alice, Scratch, and ROBOTC at the undergraduate level. While working for Robomatter, Inc., an educational robotics company, he developed STEM educational solutions that emphasized computational thinking and age-appropriate programming skills, and conducted professional learning for educators online and face-to-face on how to value and integrate computational thinking practices into classrooms. He is currently a postdoctoral research associate and the project leader of a cybersecurity micro-credential at the University of Wyoming. Dr. Mugayitoglu has more than 16 publications, including peer-reviewed conference papers, conference posters, conference presentations, a journal article, and a book chapter.

Dr. Mike Borowczak, University of Wyoming

Dr. Mike Borowczak is an Assitant Professor of Computer Science and the Director of the Cybersecurity Education and Research center (CEDAR) at the University of Wyoming. He earned his Ph.D. in Computer Science and Engineering (2013) as well as his BS in Computer Engineering (2007) from the University of Cincinnati. His research focused on detection and prevention of information leakage from hardware side channels. His current research interests include investigating the safety, resilience, and security of decentralized components, devices, and system architectures from theoretical modeling, to simulation and practical implementations. He is also involved in K-20 CS/cybersecurity education research and was the 2019 RMS ASEE conference co-chair.

Mike also has over a decade of industry and research experience – mostly revolving around the semiconductor and bioinformatics industries – with specific experience at Texas Instruments, Intel, and Cincinnati Children's Hospital Medical Center. In addition to his industry experience, Mike spent two years, while completing his Ph.D., as a National Science Foundation GK-12 fellow – teaching and bringing real-world STEM applications in two urban high schools. Since then, he has worked with university faculty to promote and extend K20 STEM outreach in Ohio, Oregon, Texas, and Wyoming. He has authored peer-reviewed articles and papers, presented at national and international conferences, and taught undergraduate/graduate courses in Computer Security, Data Mining, VLSI and pedagogy in STEM.

Dr. Andrea Carneal Burrows, University of Wyoming

Dr. Andrea C. Burrows is a Professor and Associate Dean for Undergraduate Programs at the University of Wyoming (UW) in the College of Education (CoEd).She received her doctorate degree from the University of Cincinnati in 2011.She was awarded the UW CoEd Early Career Fellowship (2013), UW CoEd Faculty Award for Outstanding Research and Scholarship (2015), UW CoEd Faculty Award for Outstanding Service to the Education Profession (2016), UW CoEd Honored Fall Convocation Faculty (2017), and UW CoEd Faculty Award for Outstanding Research and Scholarship (2019).Since beginning at UW, Burrows has written, implemented, or evaluated over 50 unique grants. She has been the Program Director for GenCyber as well as PI of NSF grants for STEM and CS work. The core of her research agenda is to deepen science, mathematics, engineering, and technology (STEM) partnership involvement and understanding through STEM interdisciplinary integration with in-service teacher professional development (PD) and pre-service teacher coursework. Her research agenda is composed of a unified STEM education partnership structure and connects educational research to real-world practices.Burrows' many publications appear in leading journals.She is the Co-Editor ofCITE-Journal Science(www.citejournal.org). She is active and presents in several organizations such as AERA, ASEE, ASTE, NSTA, and SITE.Before

beginning her work in higher education, she taught secondary school science for 12 years in Florida and Virginia (USA).

Designing a Creative Cybersecurity Micro-credential for Educators: Challenges and Successes of K-12 Teacher Professional Development

Bekir Mugayitoglu, Mike Borowczak and Andrea Carneal Burrows
University of Wyoming
bmugayit@uwyo.edu, mike.borowczak@uwyo.edu, andrea.burrows@uwyo.edu

Abstract

Developing foundational cybersecurity knowledge within our society is a critical need for our well-being and protection. At present, there is a dearth of access to fundamental cybersecurity knowledge within student and educator populations. This study can inform engineering educators through professional development with its use of design thinking strategies and be used as a model. With this concept in mind, this study focuses on the impact of a short-term (few week) cybersecurity micro-credential for K-12 teachers that included resources that aligned to the needs of their students. Over the of two iterations of this micro-credential study, the authors sought to answer the research question, "What are the micro-credential cybersecurity successes and challenges identified by the participants based on design thinking framework?" A total of 21 K-12 teacher participants engaged with two micro-credential experiences. The micro-credential includes unplugged activities via cybercards, essential vocabularies, and online research-backed resources and focused on an introduction to cybersecurity, the CIA Triad (Confidentiality, Integrity, and Accessibility), Abstraction, Modularity, and Least Privilege. This study utilized a mixed-methods approach. Qualitative data included observational field notes, bi-weekly progress reports, researcher interviews of 13 K-12 teachers, and notes from a focus group meeting with the K-12 teacher participants. The semi-structured interview questions focus groups notes, and bi-weekly progress reports were coded and grouped into major themes. Additionally, quantitative data including sub-scale concerns were obtained from the attitude survey responses. Using qualitative and quantitative analysis methods, the authors isolated specific successes and challenges experienced by K-12 teachers during their engagement with the pilot micro-credentials. Findings include a positive impact on the concerns about computer science between pre-test, post-test, and secondary post-test scores. Additionally, there is a relationship between specific micro-credential materials and teacher's self-confidence at integrating cybersecurity concepts within their own K-12 classroom. The limitations are included. The study showcases innovative and practical tools for teaching cybersecurity, and has implications for teacher educators, technology educators, and those that work in local, state, national educator spaces, and those creating and implementing professional development.

1. Introduction

Today, not only is cybersecurity one of the fast-growing and most in-demand fields in the United States, but basic cyber-hygiene is becoming a must-have skill for all (Vishwanath et al., 2020). Based on the current reports, 2021 is forecasted to have a demand for up to 3.5 million cybersecurity-related jobs (Sohime, Ramli, Rahim, & Bakar, 2020; Ventures, 2017). Additionally, Risk Based Security (2020) reports that 2019 saw over 7,000 unique breaches exposing over 15 billion individual records and analysis of the breached records show a fundamental lack of even basic cyber hygiene skills. In order to address these emerging threats and needs, our K-12 schools could provide an opportunity to reach a significant portion of the population by enabling students to learn foundational tenets of cybersecurity before entering college. This study can inform engineering educators through professional development (PD) with its use of design thinking strategies and be used as a model. With this concept in mind, this study focuses on the impact of a short-term (a few week) cybersecurity micro-credential for K-12 teachers that included resources that aligned to the needs of their students. In general, the micro-credential can be used for not only K-12 teachers and students, but also as PD for college educators and students as well as community members.

Most current K-12 teachers lack the confidence and basic cybersecurity knowledge to embed and teach cybersecurity content within their classrooms (Maina, Smit, & Serwadda, 2021). Compounding the issue, aside from the NSA's GenCyber program (Wolf, Burrows, Borowczak, Johnson, Cooley, & Mogenson, 2020), there are few PD that provide opportunities for educations to gain that critical cybersecurity foundational knowledge (Maina, Smit, & Serwadda, 2021). In 2020, the limited number of PD opportunities was further hampered by COVID-19 which affected and limited, traditional in-person activities and dramatically decreased K-12 teacher opportunities. As a result, virtual PD demand increased more than ever – including micro-credentialing. Micro-credentials are typically a virtual-oriented, mastery-based, personalized approach to demonstrate specific knowledge and skill (Acree, 2016; Berry, 2017; Patrick, Worthen, & Frost, 2017). Instruction can be provided in a completely online environment, is self-paced, and is focused on one specific competency at a time (Abramovich, 2016). Though K-12 teachers can use a micro-credential to learn new cybersecurity content knowledge, pedagogical knowledge, and strategies to teach their students, not all of them are helpful for K-12 teachers to learn new things and teach their students (Gauthier, 2020). First, cybersecurity is part of computer science PD and it is designed to deliver as a module or sub-module instead of the whole PD at one time. Thus, the researchers sought to develop this cybersecurity-focused micro-credential for computer science and STEM teachers [i.e., non-computer science teachers but teachers of science, technology, engineering, and mathematics (STEM) subjects in this study] alike. A ground up development of a cybersecurity micro-credential enables the researchers to develop, expand, and tailor materials for a wide variety of target audiences – from individual state requirements (e.g., when cybersecurity is a portion of a larger set of CS standards) or more general national-objectives. To accommodate this flexible, ground up approach the researchers aimed to build infrastructure (i.e., micro-credentials) to support rigorous and content-rich, virtual PD for K-12 teachers to instill cybersecurity principles and content knowledge in their students (Dark and McNair, 2015).

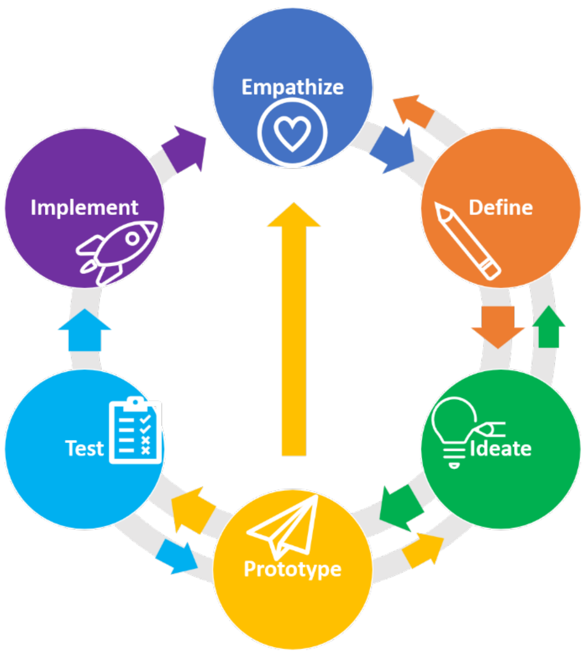
The micro-credential PD that was created utilized Loucks-Horsley's (2010) seven principles that are common to effective PD experiences for STEM teachers including: 1) revolving around clarity related to teaching, 2) broadening opportunities for teachers, 3) mirroring/modeling instructional methods for the teachers to use with their students, 4) encouraging teachers to form learning communities with other STEM teachers, 5) developing leadership among teachers, 6) teaching or linking across the curriculum, and 7) continually assessing the PD process.

2. Design Thinking Framework

Design thinking is the technique which is useful in the development of a new product, in this case, a micro-credential used for PD. This is a human-centered approach to implementation and has six stages (see Figure 1) including *empathize, define, ideate, prototype, test, and implement* (Goldman & Kabayadondo, 2017; Kelley & Kelley, 2013).

Figure 1

The cyclic nature of the design thinking framework with six key stages that result in implementation



With the design thinking framework and human-centered design as a basis, this micro-credential utilized a continuing participatory approach to PD. While designing the micro-credential, the researchers included, and valued K-12 teachers' voices a part of process. In doing so, the researchers consciously worked towards implementing a cybersecurity micro-credential to serve computer science teachers and STEM teachers alike. The team aimed to support K-12 teachers in learning how to tackle "wicked problems" while teaching, implementing, and utilizing activities with their students in the classroom (Diefenthaler, Moorhead, Speicher, Bear, & Cerminaro, 2017; Kelley & Kelley, 2013; Marks, 2017; Razzouk & Shute, 2012).

Educationally focused PDs are often created to be pertinent to the content, standards, and grade level of the participants based on needs defined by a district or state. However, this approach is often not inclusive of individual teachers. Especially in STEM subjects, it is important to include teachers while adding fundamental content knowledge with effective pedagogical approaches (Burrows, 2015; Burrows & Borowczak, 2016; Loucks-Horsley, 2010). Based on the design thinking framework, teachers are not only end-user or "content user" stakeholders but they are also a part of the main design thinking process phases and provide valuable feedback and insights through empathy maps and in-depth interviewing during the prototyping phase. For K-12 teachers to prepare their students to become cyber-literate, digital cyber-creators, they are most effective when provided content knowledge in conjunction with specific pedagogical content knowledge. That is why empathy map personas are used after pilot testing (Siegel & Dray, 2019). Thus, the researchers re-designed the micro-credential experience after gathering insights and testing it based on teachers' empathy map from the first micro-credential study.

3. Problem, purpose and research questions

Research Questions

Motivated by the current needs for new types of cybersecurity PD opportunities, the current literature, and a project that had potential to address some existing gaps, the researchers were motivated to answer the following research questions:

1. How do K-12 teachers' attitudes towards computer science education change over a few weeks of a cybersecurity micro-credential PD?
2. What are the successes and challenges of a micro-credential PD as identified by the K-12 teacher participants?
3. What are K-12 teachers' concerns regarding the integration of cybersecurity in the classroom?

4. Methods and Analysis

This was a mixed methods study conducted during a micro-credential study in 2020 that included qualitative, semi-structured interviews and quantitative, attitude surveys data. The K-12 teachers participated in a four-week (Pilot 1) and a six-week (Pilot 2) online self-paced cybersecurity micro-credential. The micro-credential PD team (i.e., engineering faculty, education faculty, post-doc, engineering college students, education college students) prototyped materials and tested techniques that supported teachers in cybersecurity/computer science education. The K-12 teachers assisted with testing and evaluating a pilot cybersecurity micro-credential that could be implemented in 2021. Additionally, the researchers provided teacher participants with two 1-hour virtual office-hour sessions per week along with asynchronous mentoring. By focusing on teacher preparation, the cybersecurity micro-credential empowered K-12 teachers through mentoring. Additionally, content-rich cybersecurity unplugged and plugged lesson plans instructed teachers how to integrate cybersecurity principles and concepts into their pedagogy.

The researchers launched the Pilot 1 and Pilot 2 studies, tested Modules 0 & 1 as part of the micro-credential (see Figure 2), and received feedback via bi-weekly progress reports, semi-structured interviews, and focus group interviews. In particular, semi-structured interviews provided qualitative data about K-12 teachers' competency and quantitative data about perceptions. Based on their feedback and insight, the researchers developed and tested modules 0 through 4 (see Figure 3 - Introduction to Cybersecurity; CIA Triad: confidentiality, integrity, and availability; Abstraction, Modularity, and Least Privilege) based on K-12 teacher/student needs.

Figure 2

First created micro-credential PD modules (0 & 1)

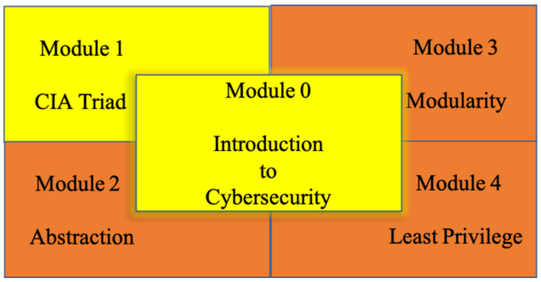
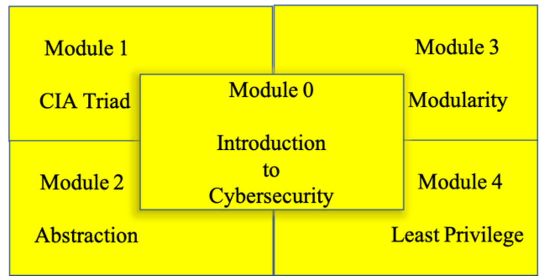


Figure 3

Iteration of micro-credential PD modules (0, 1, 2, 3 & 4)



The K-12 teachers learned how to use cybersecurity concepts and principles to make connections while demonstrating their competency via a variety of assessment choices. The process aided the micro-credential PD team in transforming a traditional PD program into a technology rich, self-paced, virtual PD opportunity to address the needs of rural K-12 teachers. Most importantly, this micro-credential blended educational design and PD training to introduce a more innovative approach to making sense of how decisions are made about the micro-credential approach.

In this study, both qualitative and quantitative data was collected and included: 1) 36 total responses pre/post/post-post Likert-scale attitude questions (quantitative), 2) thirteen (13) semi-structured interviews, and 3) two focus group sessions (qualitative). Additionally, two surveys were distributed before the cybersecurity micro-credential. The first survey focused on K-12 teachers' demographics, and the second survey focused on K-12 teachers' attitudes toward computer science. Finally, an attitudes survey was conducted three times (pre-micro-credential Pilot 1, post-micro-credential Pilot 1, and post-micro-credential Pilot 2).

The attitude survey measured K-12 teachers' attitudes toward computer science utilizing 29 questions (Ravitz, Stephenson, Parker, & Blazevski, 2017). This attitude survey asked the K-12 teachers to respond to statements on a 1 to 5 Likert scale where a response of "1" demonstrated that they strongly disagreed and a response of "5" indicated that they strongly agreed with the statement (1= Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree and 5= Strongly Agree).

During Pilot 2, eight of the 16 K-12 teacher participants were interviewed by the research team. In order to support qualitative research of perception, one of the interview questions was an open-ended attitude question and is shown in Table 1.

Table 1

Semi-structured interview, open-ended attitude question

Question
Describe your attitude toward computer science/cybersecurity now, as compared to before you did this micro-credential: more positive, same, or more negative. So how did you feel about it, and are you more confident?

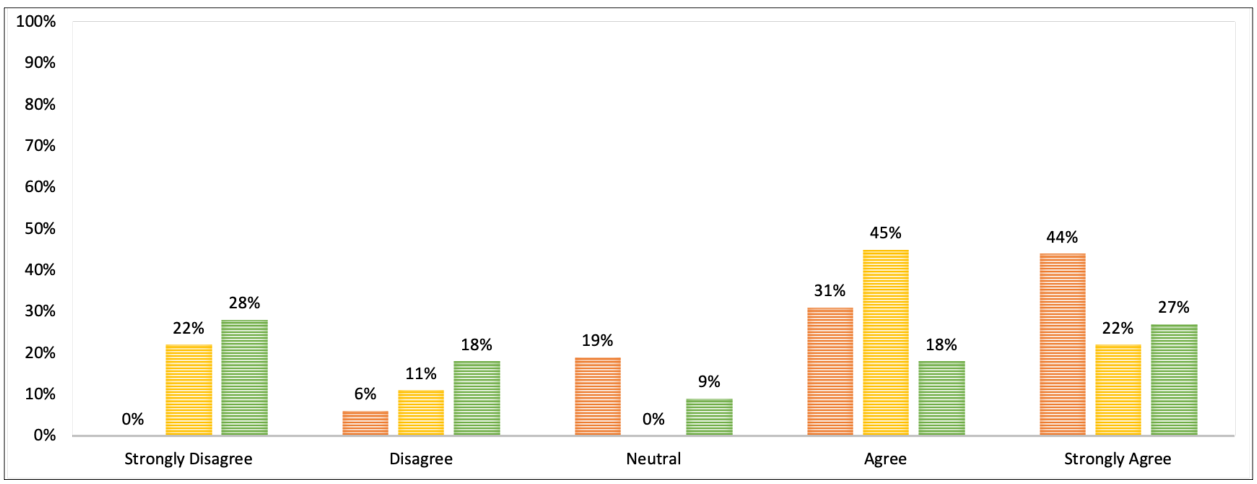
5. Findings

Quantitative Results

Quantitatively, the researchers present evidence of concerns about the cybersecurity micro-credential based on questions 8 and 9 of the perception/attitude survey (see Figures 4 and 5).

Figure 4

*Teacher responses on survey question #8: "*I am concerned about improving how I teach CS." *Each set of 3 bars from left to right represent pre, post, and post-post survey responses respectively.*

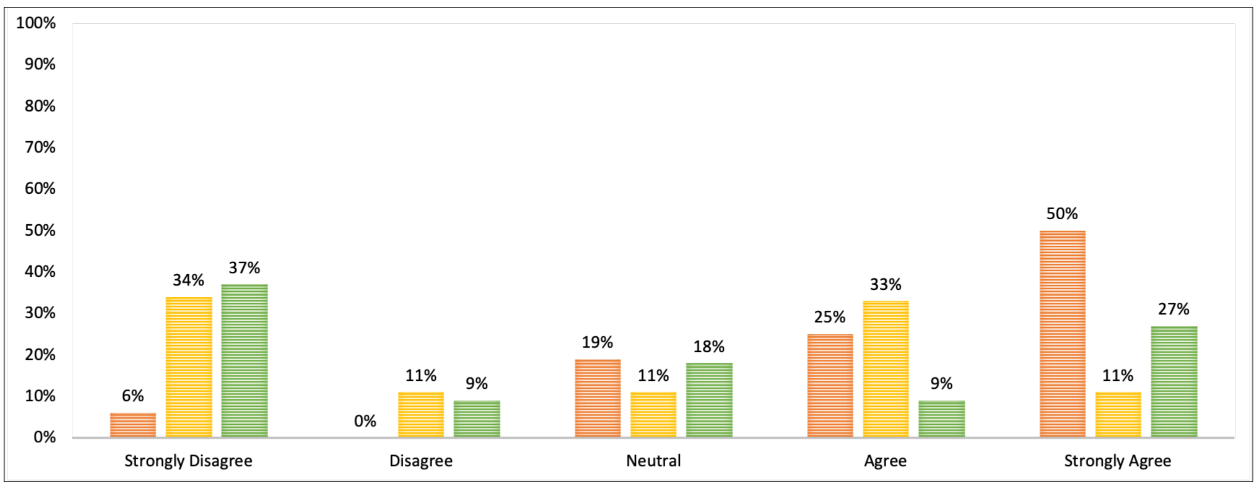


Question number eight (#8) asked teacher participants to respond to the following: "I am concerned about improving how I teach CS" (Ravitz, Stephenson, Parker, & Blazevski, 2017). On the pre-survey (n=16), a majority (75%) of the K-12 teachers' responses were 'strongly agree' and 'agree' that they were concerned about improving how to teach computer science in their classroom. On the first post-survey (n=11), a majority (77%) of the K-12 teachers' responses were 'strongly agree' and 'agree' to improve how to teach computer science in their classroom. On the post-post-survey (n=9), the agreement (strongly agree and agree) switched from 77% to 45%, meaning that the K-12 teacher participants were less concerned about personally improving how to teach computer science.

Question number 9 (#9) asked them to respond to the following: "I am concerned about working to improve how CS is taught" (Ravitz, Stephenson, Parker, & Blazevski, 2017). On the pre-survey (n=16), a majority (75%) of the K-12 teachers' responses were 'strongly agree' and 'agree' that they were concerned about improving how computer science is taught. On the first post-survey (n=9), the agreement (strongly agree and agree) decreased from 75% to 44%, meaning that the K-12 teacher participants were less concerned about personally working to improve how computer science is taught. On the post-post-survey (n=11), a minority (36%) of the K-12 teachers' responses 'strongly agree' or 'agree' that they were concerned to improve how to teach computer science.

Figure 5

Teacher responses on survey question #9: "I am concerned about working to improve how CS is taught." Each set of 3 bars from left to right represent pre, post, and post-post survey responses respectively.



Both question items indicate that K-12 teachers tend to be concerned, at least to some degree, about teaching computer science. Potentially because of the micro-credential PD which included sample resources such as lesson plans, flashcards, and unplugged activities these concerns decreased. In particular, the K-12 STEM teachers (those that were other than computer science teachers) who were provided with sample lesson plans on cybersecurity and computer science concepts and principles were overall less concerned about integrating cybersecurity in their classrooms. Yet, some teachers' attitudes about integrating computer science in their classrooms did not change even when they obtained the micro-credential PD materials.

In the beginning of the micro-credential PD, the K-12 teachers were more concerned about using cybersecurity, as most likely they did not know how to make the connection between each chosen PD module to their subject area. Additionally, K-12 teachers were concerned about whether they were able to utilize cybersecurity in their classroom. In particular, STEM teachers were able to connect cybersecurity with their subject area such as math, and science (as also shown in Sheingold et al., 1990).

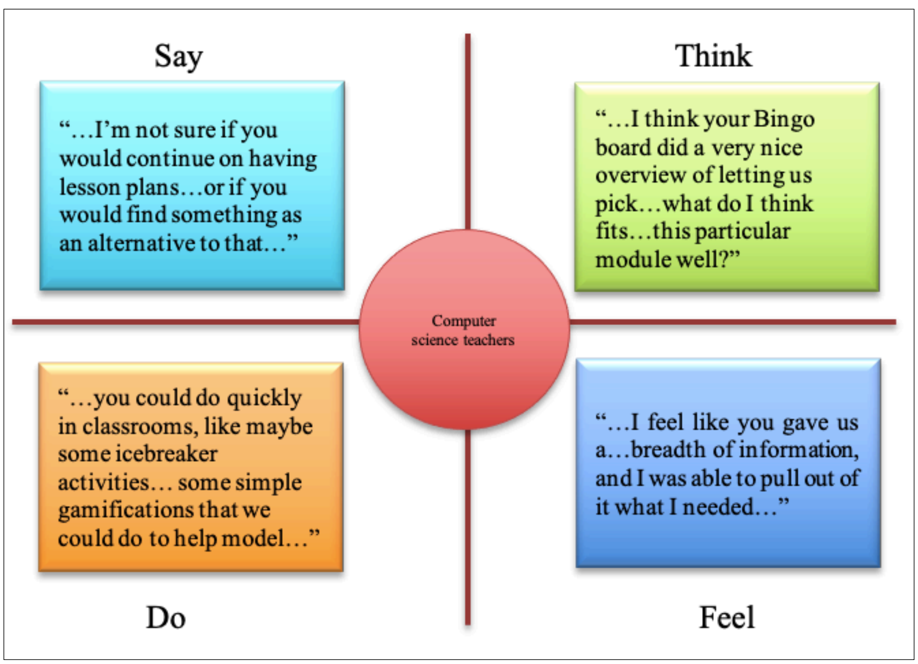
Qualitative Results

The micro-credential PD study, with two pilot studies included, highlights the successes and challenges of conducting a virtual asynchronous cybersecurity micro-credential PD via empathy maps. One of empathy maps was related with a computer science teacher persona and another one was related with a STEM teachers' persona.

An empathy map was used at the end of Pilot 1 to empathize what computer science and STEM teachers *say, think, do, and feel* during the micro-credential PD (see Figure 6). Therefore, the researchers conducted an empathy map tool to re-prototype Pilot 2 as a teacher-centered approach. Empathy maps allowed the researchers to understand the situation from the teachers' perspective during the micro-credential. This allowed the researchers to 'tune in' to teacher needs and feelings towards the micro-credential PD, so that it could be personalized, and it provided an engaging learning experience (Acree, 2016). Although empathy is intangible, it was a powerful tool for picturing insights about computer science and STEM teachers. In Figures 6 and 7, computer science and STEM teachers are the end users. Accordingly, just after Pilot 1, the teachers were interviewed about going through their pilot experience (Siegel & Dray, 2019).

Figure 6

K-12 teachers empathy map responses about the micro-credential PD

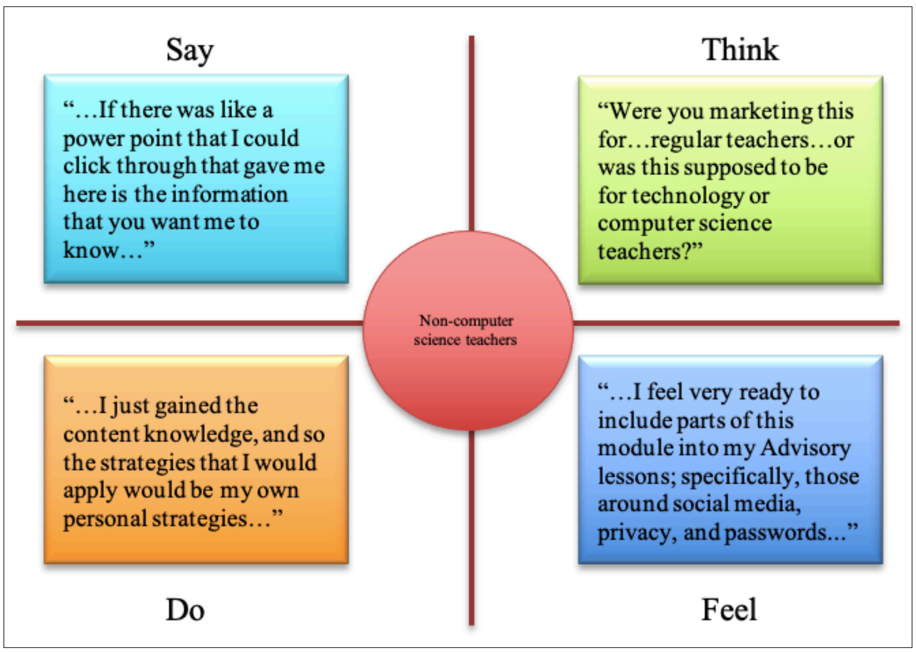


In Pilot 1 of the micro-credential PD, one of the fundamental challenges was that STEM teachers could not identify relevant cybersecurity information. Additionally, the provided resources were often technical, particularly journal articles. Furthermore, the micro-credential PD structure was different than a typical college course, and some K-12 teachers may not have been familiar with self-paced learning even as they were provided with virtual office hours for support (see Figure 7). However, computer science teachers might have been familiar with the cybersecurity content, and thus, they could more easily identify relevant cybersecurity information.

After refining and revising the micro-credential PD based on Pilot 1, using the empathy map and semi-structured interviews, the researchers re-prototyped the micro-credential PD and re-tested it with more K-12 teachers in Pilot 2. One of the successes was that some of the teachers had more confidence and less concerns regarding teaching cybersecurity in the classroom.

Figure 7

STEM teachers empathy map responses about the micro-credential PD



These responses also support that the design thinking framework which allowed the researchers to personalize modules as opposed to a one-size-fits-all approach. In other words, the teachers chose what they needed to teach their students. Other studies support these findings, that teachers provided with required resources and recommended materials (like lesson plans) more often utilize cybersecurity principles in their classroom. For example, STEM teachers, such as science teachers, were provided sample lesson plans to connect cybersecurity with their current subject area (Google Inc. & Gallup Inc., 2016; Qian et al., 2018).

6. Limitations, Conclusions, and Implications

One of the main limitations of this study was a limited participant pool. The research study was conducted with only five K-12 teachers for Pilot 1 and 16 K-12 teachers for Pilot 2 (n=21), which does not represent a sample size to generalize to a larger K-12 teacher audience. Second, the K-12 teachers needed mentorship during the asynchronous environment of the micro-credential PD, in particular, the STEM non-computer teachers, and this may not have been provided as much as needed for a successful teacher micro-credential PD experience. Third, there were multiple resources provided, and K-12 teachers who were inexperienced with cybersecurity might have been overwhelmed with where to start or what to do during the micro-credential PD that focused on cybersecurity content.

These findings have overarching implications for utilizing the design thinking framework in development of the micro-credential PD. Through the research study (with Pilots 1 and 2) and based on the focus group and in-depth interview responses, findings indicated that computer science and STEM teachers benefited from the resources and sample lesson plans. Based on previous studies and this study, the researchers believe that the sample lesson plans allowed teacher participants to make the connections between their current teaching area and cybersecurity principles. More research in this area is warranted.

Some lessons learned from the micro-credential creation team included using appropriately leveled resources and getting feedback consistently during the micro-credential PD work. Based on the feedback and results of the study, the researchers plan on iterating current unplugged and plugged activities and developing more unplugged/plugged activities for subsequent micro-credential PDs. The aim is to enable teachers in synthesizing and understanding the connections of cybersecurity, computational thinking, and their own subject area (i.e., STEM integration). The following paragraphs relate back to solid STEM PD practices and how the micro-credential PD team addressed them.

Resources are critical for PD participants. Throughout the study, the researchers recognized that some of the K-12 teachers were keen to share some of the resources they accessed during the micro-credentials (e.g., videos and journal articles) with their K-12 students. Materials related to computational thinking were well-received. Computational thinking materials enabled educators to transfer their knowledge not only to connect with cybersecurity but other subjects' areas including STEM disciplines. In addition to articles, the videos were a powerful resource for STEM teachers to explore new concepts while also enabling computer science teachers to understand concepts more deeply and comprehensively. Most videos were chosen for the short length, high-quality, and relevancy in computer science education.

The K-12 teachers had an opportunity to interact and explore big idea examples such as the live cyber threat map plugged activity. This is an example of modeling instructional methods for the teachers to use with their students. This plugged activity was demonstrated as a part of Module 0 (Introduction to Cybersecurity), Module 2 (Abstraction), and modeled for teachers as the threat map of the world to allow them to practice and perform with their students. This activity also allowed them to use and share their observations with students and their peers. The model most likely helped teachers to recognize one of the real-life applications of cybersecurity and then allow their students to take daily data from the map to see trends as the unit progressed.

The teachers formed their own learning community (another good STEM PD practice), as the teachers organically and informally contacted other teachers while developing their lesson plans and designing their e-artifacts (e.g., presentation, teaching video), in particular, teachers who already knew each other and taught in the same school district or school would reach out to a peer for feedback. Teachers built their own community while taking the cybersecurity micro-credential PD (Pilot 1 and Pilot 2).

Other good PD practices such as clarity in teaching, linking across the curriculum, broadening teacher participation, and developing teacher leaders were also shown in the micro-credential PD. Researchers provided free resources including unplugged and plugged activities to be used for preparing K-12 teachers to educate students and also to be the teacher-leaders in computer science/cybersecurity. The teachers examined the provided resources and even passed them along to their co-workers. Therefore, participants were being teacher-leaders to share with other teachers so that non-participant teachers would be able to use the cybersecurity content in their classrooms as well. With these connections in mind, the teachers with both cybersecurity and non-cybersecurity backgrounds were able to find meaningful connections between cybersecurity and their current content areas. Unplugged activities, plugged activities, and computational thinking flashcards enabled the K-12 teachers to make the connection between cybersecurity and their subject area. For example, the Caesar cipher activity allowed teachers to practice math skills such as subtraction and addition while learning about cybersecurity and also the history of the Caesar cipher as well. Additionally, as described earlier, the cyber threat map allowed them to learn about the geography of the world.

Another strong PD concept is assessing the PD process. The micro-credential PD was prototyped and then re-prototyped using K-12 teacher feedback of Pilot 1 and Pilot 2, respectively. Researchers continually assessed, evaluated, and developed the modules based on the K-12 teachers' insights. The teachers provided feedback that the sample lesson plans were the most helpful PD aspect in developing their cybersecurity content and pedagogical knowledge. In particular, lesson plans and unplugged activities showcased a means of constructing learning and then teaching for them.

Based on the research study conducted and the experiences of the researchers, the PD creators should offer opportunities for their participants to provide feedback early and often – and this feedback should be on all facets of the PD – from content, to delivery, to its fit/adoption within the target participant pool. In addition, the selection of materials for participants should be purposeful, targeted, and licensed for educational reuse. These lessons can guide professional developments for not only K-12 teachers, but also for engineering educators in cybersecurity and computer science.

Funding:
This work was supported by the Wyoming Department of Education (WDE) and the National Science Foundation (NSF) through the CS for All: RPP - Booting Up Computer Science in Wyoming (WySLICE Award #1923542) and Sustaining Wyoming's Advancing Reach in Mathematics and Science (SWARMS Award #1339853). Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NSF.

References

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

Acree, L. (2016). Seven lessons learned from implementing micro-credentials. Raleigh, NC: Friday Institute for Educational Innovation at the NC State University College of Education.

Burrows, A. C. (2015). Partnerships: A systemic study of two professional developments with university faculty and K-12 teachers of science, technology, engineering, and mathematics. *Problems of Education in the 21st Century, 65*, 28.

Burrows, A. C., & Borowczak, M. (2016). Arduinos and Games: K-12 Teachers Explore Computer Science (Evaluation). In 2016 ASEE Annual Conference & Exposition.

Berry, B. (2017). Micro-credentials: The badges of professional growth. *The Education Digest,* 82(9), 21.

Dark, M. & McNair, B. (2015). GenCyber Evaluation Report

Diefenthaler, A., Moorhead, L., Speicher, S., Bear, C., & Cerminaro, D. (2017). Thinking and Acting Like a Designer: How design thinking supports innovation in K-12 education. Wise & Ideo. Retrieved, 6(3), 2018.

Gauthier, T. (2020). The value of microcredentials: The employer's perspective. *The Journal of Competency-Based Education, 5*(2), e01209.

Goldman, S., & Kabayadondo, Z. (Eds.). (2016). *Taking design thinking to school: How the technology of design can transform teachers, learners, and classrooms*. Taylor & Francis.

Google Inc., & Gallup Inc. (2016). Trends in the state of computer science in US K–12 schools.

Kelley, T., & Kelley, D. (2013). Creative confidence: Unleashing the creative potential within us all. Currency.

Loucks-Horsley, S. (2010). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Maina, F., Smit, J., & Serwadda, A. (2021). Professional Development for Rural Stem Teachers on Data Science and Cybersecurity: A University and School Districts' Partnership*. Australian and International Journal of Rural Education, 31(*1), 30-41. Retrieved from https://journal.spera.asn.au/index.php/AIJRE/article/view/291

Marks, J. (2017). The impact of a brief design thinking intervention on students' design knowledge, iterative dispositions, and attitudes towards failure (Doctoral dissertation, Columbia University).

Patrick, S., Worthen, M., & Frost, D. (2017). Redesigning Systems of Assessments for Student-Centered Learning. Issue Brief. iNACOL.

Qian, Y., Hambrusch, S., Yadav, A., & Gretter, S. (2018). Who needs what: Recommendations for designing effective online professional development for computer science teachers. *Journal of Research on Technology in Education, 50*(2), 164-181.

Ravitz, J., Stephenson, C., Parker, K., & Blazevski, J. (2017). Lessons from evaluation of computer science teacher professional development in Google's CS4HS program. ACM Transactions on Computing Education. 17(4), 1-16.

Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important?. *Review of Educational Research, 82*(3), 330-348.

Risk Based Security (2020). 2019 Year End Report: Data Breach QuickView. Accessed Feb 26th 2021.

Sheingold, K., & Hadley, M. (1990). Accomplished teachers: Integrating computers into classroom practices. New York: Bank Street College of Education, Center for Technology in Education.

Siegel, D., & Dray, S. (2019). The map is not the territory: empathy in design. *Interactions, 26*(2), 82-85.

Sohime, F. H., Ramli, R., Rahim, F. A., & Bakar, A. A. (2020, August). Exploration Study of Skillsets Needed in Cyber Security Field. In 2020 8th International Conference on Information Technology and Multimedia (ICIMU) (pp. 68-72). IEEE.

Ventures, C. (2017). Cybersecurity Jobs Report. Herjavec Group.

Vishwanath, A., Neo, L. S., Goh, P., Lee, S., Khader, M., Ong, G., & Chin, J. (2020). Cyber hygiene: The concept, its measure, and its initial tests. Decision Support Systems, 128, 113160.

Wolf, S., Burrows, A. C., Borowczak, M., Johnson, M., Cooley, R., & Mogenson, K. (2020). Integrated Outreach: Increasing Engagement in Computer Science and Cybersecurity. *Education Sciences, 10*(12), 353.