Self-paced E-learning: Exploring the Development of a Cybersecurity Micro-credential through K-12 Teacher Professional Development

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Abstract: This work discusses ongoing experiences in creating interdisciplinary solutions to the development of cybersecurity/computer science skills for K-12 teachers. Participants for this work were K-12 teachers; the work was conducted during the summer semester of 2020. Nine K-12 teachers enrolled in the pilot course, and five K-12 teachers completed modules 0 & 1 of the cybersecurity course. This work describes a month long, self-paced cybersecurity micro-credential which consisted of an introduction to cybersecurity and the CIA Triad (Confidentiality, Integrity, and Accessibility). The primary research question explores the extent to which the cybersecurity micro-credential was considered helpful in understanding cybersecurity concepts and principles. The authors utilized quantitative and qualitative data collection via four methods: 1) content knowledge quiz (quantitative); 2) focus group (qualitative); 3) five semi-structured interviews (qualitative) and 4) two bi-weekly progress reports (qualitative). Qualitatively, focus group, semi-structured interview questions, and bi-weekly progress reports were coded and grouped into major themes by searching descriptive words. Quantitatively, a moderate positive relationship was found between post-test scores and total time in hours spent on modules 0 & 1. The main limitation is the sample size (n=5), which is too small to produce generalizable results. The work showcases innovative tools for teaching cybersecurity.

Keywords

Cybersecurity Education, Computer Science, Micro-credential, K-12 Professional Development, Teacher Education

Introduction

K-12 teacher professional development (PD) and gaining endorsements currently have few pathways (Burrows et al., 2016). At the moment, most K-12 professional development opportunities are based on seat time, rather than what has been learned, and require travel, either for a guest speaker or for the teachers (Erickson, 2019; Muñiz, 2018). Gaining endorsements often involves attending a college or university, which may limit teachers' attendance because of time constraints as well as requiring travel for many teachers. In some areas of the country, travel is often difficult due to unpredictable weather, and teachers may have to travel several hours each way to attend in-person classes (Fredregill, 2020). Many of the classes required for teachers to gain an endorsement have no pedagogical component, leaving teachers scrambling to find resources to help them teach the subject area. Computer science and cybersecurity are prime examples of this, as many school districts are trying to rapidly certify teachers (Bentley, 2019). To help their teachers with these issues, many districts and states have turned to micro-credentials as a potential solution, often using national vendors such as Bloomboard and Digital Promise (Digital Promise, 2018). Micro-credentials are an up-and-coming curriculum delivery format that many states are developing for use with K-12 teachers (Coyne, Hollas, Lane, & Christina, 2019). This work explores the journey of five teachers navigating a pilot cybersecurity micro-credential.

Literature Review and Significance of Work to the Field of Teacher Education

Access to high-quality PD is a necessary practice if school districts desire to effectively support their teachers. This is especially true in the computer science and STEM disciplines as some of the necessary skills to be an effective K-12 teacher can only be taught in PD sessions (Menekse, 2015). In order for PD to be of high quality, it must include the following components: development of proficiency in core concepts, production of materials for classroom instruction, examples of using authentic science and inquiry applications, discussion of socio-scientific issues, opportunities to use and reflect on skills being taught, and development of professional relationships between teachers (Burrows et al., 2016).

One example of PD is a micro-credential. A micro-credential course is a cost-effective, self-paced, time-flexible, competency-based, and research-backed online platform (Bartz & Kritsonis, 2019; Brown, 2019; Crow, 2017). Micro-credentials must be accepted by the state licensure board, which has led many states to create their own to ensure their quality. Micro-credentials serve as an alternative pathway to certification in a specific area as well as professional development. Micro-credentials are self-paced, online, and include resources that teachers can use in their classrooms (Brown, 2016). They are a potential solution to the aforementioned problems, as they require no travel, are based on outcomes rather than seat time, and are specifically geared towards teachers.

The micro-credential course described here was specifically designed to educate computer science and non-computer science teachers on foundational cybersecurity concepts. The micro-credential course consisted of sets of modules, with each module addressing cybersecurity concepts and principles based on the 11 primary principles derived from the National Security Agency GenCyber programs' Cybersecurity First Principles and Cybersecurity Concepts (Dark and McNair, 2015; GenCyber CFP, 2019; Payne, Abegaz, & Antonia, 2016). The majority of K-12 teachers are not qualified to teach cybersecurity and/or computer science due to the lack of pedagogical content knowledge, resources, and/or skills (Blanchard, LePrevost, Tolin, & Gutierrez, 2016; Menekse, 2015). Therefore, K-12 teachers do not know how to start integrating cybersecurity instruction into their classrooms and activities.

The authors created the micro-credential based on constructionism theory. Constructionism fits well with differentiated instruction since it is a learning theory that builds upon a teacher's prior computer science knowledge and experiences. Additionally, it is also a theory of "learning by doing" hands-on and minds-on learning activity (Papert & Harel, 1991). For example, the authors have created e-cybercards for teachers and their students to utilize and demonstrate their competency in cybersecurity concepts and principles. The micro-credential was implemented and distributed through the online Canvas Learning Management System platform. Continuing with this theory in mind, the micro-credential is in the prototype and pilot stage, and the authors are still exploring and experimenting which modules are of the most value to target stakeholders. However, the authors built a proof-of-concept course platform and modules for pilot testing and alteration for future use. The authors are currently focusing on scaling up content, providing clearer structure and pathways, and testing more explicitly whether science teachers (or other teachers) would and can use the cybersecurity micro-credential in classrooms.

Purpose and Research Questions

Purpose

With the increased use of technology in today's world, is important for K-12 teachers to integrate cybersecurity concepts, principles, and methods into instruction. However, there is a lack in cybersecurity education skill gap, especially teacher training in teaching cybersecurity (Caldwell, 2013; Dark & McNair, 2015). The purpose of this study was to examine whether K-12 teachers' understanding of cybersecurity concepts and principles would change if they were to take a micro-credential course focused specifically on cybersecurity (GenCyber CFP, 2019). To this end, K-12 teachers were taken in the two cybersecurity models. An evaluator examined bingo format submissions and lesson plan designs as the assessments for the course.

Research Questions

1. Did the cybersecurity micro-credential impact content knowledge of cybersecurity concepts and principles?
2. How did the micro-credential course impact K-12 teachers their knowledge of cybersecurity concepts and principles?
3. What were the cybersecurity micro-credential successes and challenges identified by the participants?

Methods, Analysis, and Findings

Methods and Analysis

This study describes a month long, self-paced cybersecurity micro-credential which consists of an introduction to cybersecurity and the CIA Triad (Confidentiality, Integrity, and Accessibility). This micro-credential pilot course covers topics such as: Malware & Ransomware, Networks, Hackers (white hat, black hat, grey hat, and more), Passwords, Social Media & Policy, Email security, and Password (common password threats, creating strong passwords, and managing passwords). The researchers contacted K-12 teachers to virtually participate in the pilot course. There were nine K-12 teachers accepted to be a part of the 1-month long pilot study. Within that period of time five K-12 teachers completed module 0 & 1 of our cybersecurity course.

This project features two phases: a pre-pilot test course with five participants taking place in Summer 2020, followed by a much larger pilot course in Fall 2020 with as many as 40 participants. The data were collected via an online-based survey with a return rate of 77.7%. One focus group and five semi-structured interviews were held during the three 15-minute virtual office hours, 1-hour introductory Zoom meeting, and the 1-hour final Zoom meeting with K-12 teachers. Five K-12 teachers had 4 weeks to complete the course material between the introductory and concluding Zoom meetings. The virtual meetings and office hours were not compulsory, but were recommended and provided a support opportunity to the participant teachers. Overall, the micro-credential course was considered helpful in understanding cybersecurity concepts and principles to K-12 teachers (n=5).

This work employed both quantitative and qualitative analyses. Researchers conducted focus group, semi-structured interviews, used observational field notes and bi-weekly progress reports. At the meetings, researchers recorded observational field notes and took meeting notes. Special attention was paid to teachers' questions, answers, concerns, and quotes. During and after the meetings, the researchers added all notes for the future analysis. The micro-credential team members observed the participants asynchronously via Canvas Learning Management System and synchronously via the Introductory Zoom meeting, final Zoom meeting, and 15-minute virtual office hours. As such, these meetings occurred before, during, and after the micro-credential course.

Qualitative Findings

Qualitative data sources consisted of field notes, a focus group, semi-structured interviews, and bi-weekly progress reports. The focus group was facilitated by the author, during which the K-12 teachers were asked 4 general questions: (1) What did you like and what didn't you like? (2) How much time did you invest in each module? Was this what you expected? (3) Which features are/aren't useful to you? What would you suggest should be changed? (4) How do you think the micro-credential would be beneficial to a computer science teacher? A non-computer science teacher? The semi-structured interviews were held after the focus group session when teachers met with experts. The observational field entries occurred throughout the pilot. These included notes based on meetings between the authors. The bi-weekly progress reports transitioned into checkpoints after completion of each module. Due to the self-paced nature of the micro-credential pilot, students finished the first module at very different times. This differential, alongside allowing for the best feedback of the modules from participants, made the transition necessary. During the micro-credential, teachers particularly enjoyed learning about cybersecurity. The K-12 teachers involved in the pilot stated, via bi-weekly progress reports, that they would be able to use the cybersecurity content in their classrooms. Participants also highlighted that they would be able to have students look at

cybersecurity from more than a technical standpoint, as after participating in the micro-credential they were better able to facilitate a greater understanding of the vocabulary and overall scope of cybersecurity.

Themes	K-12 Teacher Open Repsonse Answers
Competencies	"...I had to go back and really look through the material to complete an assessment um well, and so I thought that was a good way to handle it…" "…I'm not going to say that I knew it all ahead of time, because I did pick up a few things..."
Content	"…it also would allow you to go back and review the material as many times as you wish…" "…Reading the academic material allowed me to see if from the academic side more, so it gave me a more holistic view of the parts of the triad."
Resources	"…I felt that there was a good variety of of ways that the information was distributed, uh both in-in text and in-in video. Um, so and the video choices were-were very good…" "…I thought the flashcards and the Bingo cards and all that were actually really really-really good."
Modalities	"…quiz gave me a-a fairly good idea of whether or not I needed to go back and look at some of the material again…" "The office hours were-were really nice…"
Classroom	"…The information from the flashcards, or even the flashcards themselves is something that could be used in the classroom…"

Table 1: K-12 teachers semi-structured interview comments coded into five major themes

The themes used for coding for later data analysis were chosen based upon commonality of word used in participant answers. These themes were also chosen based upon the desired data to be collected from the participants for later choices of formatting the micro-credential modules. Authors wanted to know if the competencies gained, content, and resources presented could be useful for the participant teachers to use for teaching cybersecurity in their classrooms. This was especially important to consider when analyzing the effectiveness of the modules in providing science teachers with resources to use in cross-disciplinary approaches. Lastly, authors desired data regarding the usefulness of the modalities provided to the participants both through the LMS and in correspondence with the authors through focus group virtual sessions.

K-12 teachers provided various comments regarding the successes and challenges of the micro-credential course. Some examples of these comments are as follows:

As a success of the micro-credential course, one K-12 teacher commented,

"I think the way you have set up the micro credential is great with the built in videos and articles."

Another K-12 teacher commented,

"…the vocabulary was presented was very very good…I ended up you know jotting some notes down for me to present my students…"

As a challenge of the micro-credential course, one K-12 teacher commented,

"I have no idea if I was supposed to watch all 10 of the videos…"

More comments can be seen regarding the successes and challenges of the micro-credential course in table 2 below.

Themes		K-12 Teacher Open Response Answers
Success	Bi-weekly progress report	"…I feel confident enough that I could teach the CIA triad to students at the middle school level…" "…I do feel as if I am moving toward competency…"
	Semi-structured Interviews	"…The course was put together pretty well…"
	Focus group	"…I gained confidence in my understanding of technology that was primarily through videos…"
Challenges	Bi-weekly progress report	"…pdf documents didn't work for me…"
	Semi-structured Interviews	"…I would've considered doing the online office hours…but they were only fifteen minutes, and so the fact that they were on Saturdays…"
	Focus group	"…the layout of the course was really difficult…"

Table 2: K-12 teachers semi-structured interview, bi-weekly progress report, and focus group comments coded into successes and challenges themes

Among the feedback received commentary on the scaffolding aspect of the micro-credential.

The key essential vocabulary provided K-12 teachers while learning materials via resources and supporting journal articles. Vocabularies were aligned with check your understanding questions, journal articles, and videos. Therefore, providing and covering this vocabulary was not only beneficial for teachers, but also their students as well based on the feedback of the K-12 teachers. According to findings, K-12 teachers needed more guidance and scaffolding than the layout initially provided. As a result of this feedback, the micro-credential layout will be reconsidered to add more guidance and scaffolding for prospective module development.

Meanwhile, during the focus group, a few K-12 teachers expressed that they like the video and even wanted to use it in their classrooms after our pilot. Our videos were short, informative, technical, non-technical and provided information related to the pedagogical side of cybersecurity with tips and ideas. Research has supported that the small-size videos are more beneficial for students because of their shorter attention span (Guo, Kim, & Rubin, 2014). Videos were purposely chosen in short ranges between 4:50 to 20:41 minutes, as research shows that, after 6 minutes, student engagement with videos decreases.

Based upon the comments K-12 teachers provided through the bi-weekly progress reports, the overall consensus was that the information given through the modules was effectively organized relative to computer science content taught in university programs. Furthermore, the participants felt that the information provided about cybersecurity created new pathways for learning and teaching about online safety in their K-12 classrooms.

Quantitative Findings

The quantitative analysis in this work consists of counting the numbers of K-12 teachers. Grading in this pilot course consisted of 3 components, totaling 100 points. These components included: Mixed Test (10% or 10 points), one of the bingo format artifacts (35% or 35 points), and lesson plan (55% or 55 points). The Check Your Understanding (CYU) questions were also provided as formative questions to show researchers how the earner progressed; CYU questions were worth 0% or 0 points of the earner's grade. They also serve to show the earner how well they have grasped the material before attempting the assessments. The mixed test is technically a bingo artifact, but has been preselected as the assessment for module 0. This was done to show students how to use the bingo table and because it was the assessment that shows the least about the earner's higher-order thinking. This also made it appropriate for the introduction. The bingo artifacts included a variety of assessment types that allowed the participant teachers to demonstrate understanding of the material. The lesson plan demonstrated the student's ability to apply the concepts being discussed.

This pilot course used artifact evidence from K-12 teachers working in conjunction with quantitative data based on the teachers' work.

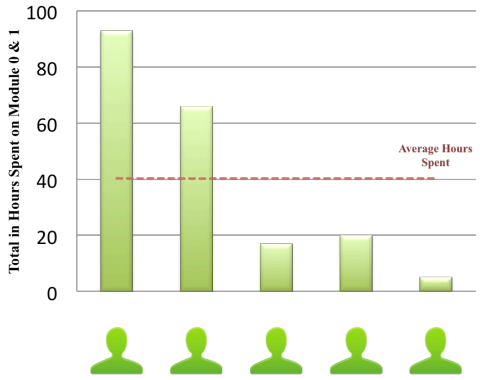

Figure 1: Total in hours spent on module 0 & 1

(Canvas learning management system)

Figure 2: Total in hours spent on module 0 & 1

(Bi-weekly progress report)

Based on the quantitative analysis, Figure 1 shows the time spent on modules 0 & 1 for each K-12 teacher based on the canvas learning management system analytics. The highest time spent was more than 90 hours and lowest time spent was less than 5 hours. The average time spent was more than 40 hours. This information indicates that the amount of time spent on resources, assessments, and submissions might vary based on teachers' cybersecurity background knowledge. The figure 2 shows the time spent on modules 0 & 1 for each K-12 teacher based on bi-weekly progress reports. For module 0, the highest time spent was 5 hours and lowest time spent was 0 hours. The average time spent was 2.3 hours. For module 1, the highest time spent was 20 hours and lowest time spent was 6 hours. The average time spent was 13.6 hours. The average of time spent on modules 0 & 1 was about 8 hours. This information indicates that the time spent resources, assessments, and submissions might vary based on teachers' cybersecurity background knowledge.

Question	Test Score
1	100%
2	50%
3	67%
4	100%
5	100%
6	100%
7	100%
8	100%
9	83%
10	83%

Table 3: Percentage of correct cybersecurity content answers for micro-credential K-12 teachers after 2 modules

Authors provided 10-question test for them after taking module 0 and 1. This table demonstrates their percentage of correct content answers. Ten questions were given after the completion of module 0 materials, "Introduction to Cybersecurity," and module 1 materials, "The CIA Triad." Based on the test scores, it was clear that from the assessment results that there was a connection between the questions asked and the resources, supporting research papers, and essential vocabularies provided.

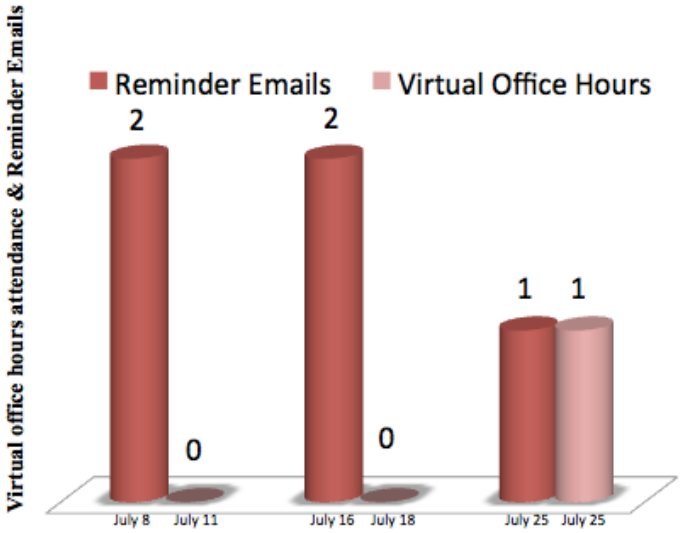

Figure 3: Virtual office hours attendance & email reminders

The majority of K-12 teachers were engaged, communicating throughout modules 0 and 1, interacting via email and even joining the Virtual Zoom meetings. Each teacher received an email reminder for 15-minute virtual office hours every Saturday and/or earlier the weekend. For example, we sent email reminders on July 8 and July 16. Also, we emailed them July 25 just before Virtual office hours. One teacher showed up during the last week of our virtual office hours. This result also supports the research that the office hours are not largely used by students (Jackson & Knupsky, 2015). The day assigned for office hours is under consideration, including providing students options for what is the best time and best day for virtual office hours since some students mentioned at the interview and bi-weekly progress report that they were not able to join because of the day and time.

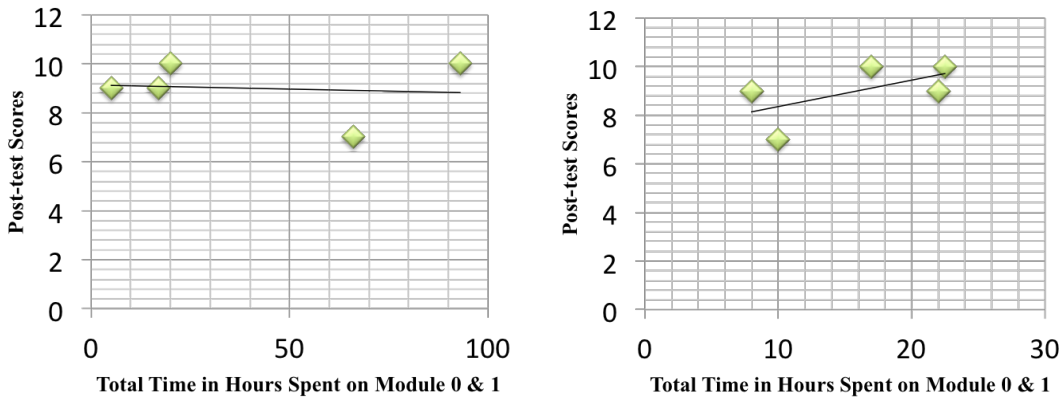

Figure 4: Post-test scores versus total time in hours spent on module 0 & 1 based on the canvas learning management system and bi-weekly progress reports

Based on the canvas learning management system analytics, the figure 4, Pearson's r correlation was used since a linear relationship between variables was being investigated. A weak negative, but nonsignificant relationship was found between post-test scores and total time in hours spent on modules 0 and 1 (r=-0.103, p=0.869). Based on the bi-weekly progress reports, K-12 teachers were also asked how long it took them to complete modules 0 and 1. Pearson's r correlation was used since a linear relationship between variables was being investigated. A moderate positive, but nonsignificant relationship was found between post-test scores and total time in hours spent on modules 0 and 1 (r= 0.594, p=0.290). These results show that there does not appear to be a statistically significant correlation between post-test scores and total time in hours spent on modules 0 & 1.

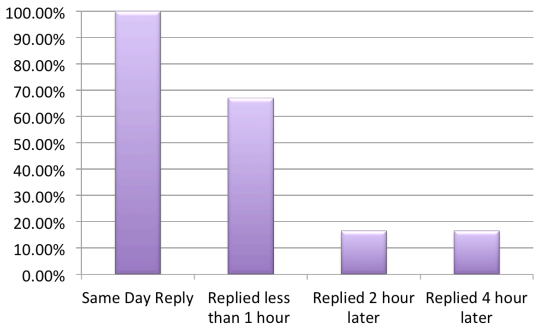

Figure 5: Hours from sent e-mail to first reply

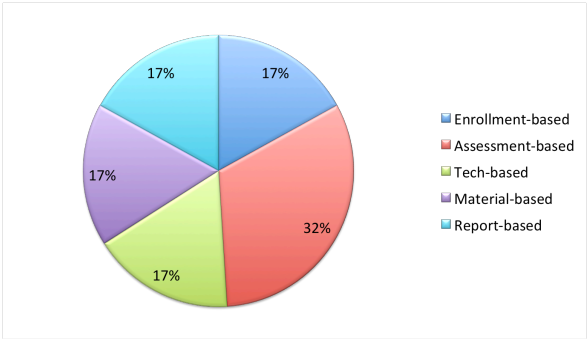

Figure 6: Question topics

Figure 5 shows, email responses to students' issues. Based on the bi-weekly progress report, two K-12 teachers mentioned that "The quick e-mail responses were greatly appreciated!" Our response rate was instant for the majority of the emails from teachers. Teachers received emails back the same day 100% of the time and the majority of responses and solving the issues discussed were replied to within less than 1 hour. A few other responses were sent out 2 hour or 4 hour after receiving the K-12 teacher's initial e-mail.

The majority of K-12 teachers communicated via email. The research has also supported this finding that emailing is the most common form of communication for students (Jackson & Knupsky, 2015). The majority of K-12 teachers' questions were based on assessment-based on our findings (Figure 6). During the final week, the K-12 teachers e-mailed us more than the previous weeks and most of their questions were related to deadlines, assessment template, and lesson plan template. In particular, some of them asked if we could provide them the assessment and lesson plan templates in word documents instead of the PDF documents which we provided through the Canvas learning management system.

Limitations and Future Research

There are several limitations regarding the current work. First and foremost, our participant sample size for this work was only five K-12 teachers, out of nine teachers who originally enrolled in the course. This work should be replicated with more K-12 teachers population, in order to provide generalized results for a larger K-12 teacher population than the community represented in this work. A larger K-12 teacher inclusive sample would generate more robust data for analysis and conclusions. Another potential limitation of this work was that K-12 teachers largely underused and disengaged the virtual office hours. Therefore, scheduling office hours is under review, since some of K-12 teachers mentioned that they were not able to join because of the day and time and thus the office hours need more flexibility to accommodate users.

Discussion and Implications

The literature explicitly states that cybersecurity and computer science education are critical for K-12 teachers. This paper details the successful pilot of a cybersecurity micro-credential course that takes an integrated approach to empower K-12 teachers with pedagogical content knowledge in cybersecurity based on both preliminary qualitative and quantitative findings. With increased content knowledge, the K-12 teachers are more likely to create and implement cybersecurity concepts and principles with their students. The program was evaluated using focus group, five semi-structured interviews, and bi-weekly progress reports which showed clear areas of success and areas in need of improvement. K-12 teachers reported that the bingo-format assessments, flashcards, and videos were the most helpful in developing their cybersecurity content knowledge. Based on the semi-structured interviews and focus group, the K-12 teachers involved in the pilot stated that they enjoyed learning about cybersecurity and would be able to use the cybersecurity content in their classrooms. K-12 teachers with both technical and non-technical backgrounds were able to find meaningful connections between cybersecurity and other content areas. The K-12 teachers also highlighted that they would be able to support students in looking at cybersecurity from more than a technical standpoint alongside being able to facilitate a greater understanding of the essential vocabulary and overall scope of cybersecurity.

The course experience outcome was an improved view of how to teach cybersecurity fundamentals online using digital tools and video conferencing technologies, connect cybersecurity content to the K-12 teacher audience, and engage future K-12 educators. As the micro-credential develops, the goal is to continue working on K–12 cybersecurity education and investigate the kinds of supports that can enable K-12 teachers to successfully complete the micro-credential. In particular, the micro-credential aims to assist K-12 teachers develop their own instructional materials, activities, and pedagogical cybersecurity and computer science content knowledge.

From the information gained during the micro-credential, it became apparent that teaching experience and prior computer science knowledge, especially in relation to cybersecurity, played an important role in how long K-12 teachers took to complete Modules 0 and 1. A weak negative relationship was found between post-test scores and total time in hours spent on modules 0 and 1 based on the Learning Management System Analytics and a moderate positive relationship was found between post-test scores and total time in hours spent on modules 0 and 1 based on the bi-weekly progress reports. The results seem to indicate that teachers with prior teaching experience and prior computer science knowledge tend to have spent relatively less time completing the modules since they were already familiar with the content, they had several years' computer science teaching experience, and prior computer science knowledge via participating in another cybersecurity professional development (i.e. Gencyber). Therefore, even K-12 teachers spent less time, however, they still scored high on the test because of aforementioned reasons. On the other hand, teachers who had no prior computer science/cybersecurity knowledge and had no computer science/cybersecurity experience spent a lot of time completing the modules but still scored below the teachers with experience in these areas on the same test. The qualitative results of the questions, which were gathered from teachers' responses, also supply this claim including interviews, focus group, and bi-weekly progress reports. Based upon the high-test scores, it became clear from the assessment results that there was a connection between the questions asked and the resources, supporting research papers, and essential vocabularies provided.

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