ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #37364

On the Development of Cybersecurity and Computing Centric Professional Developments and the Subsequent Implementation of Topics in K12 Lesson Plans (RTP)

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On the Development of Cybersecurity and Computing Centric Professional Developments and the Subsequent Implementation of Topics in K12 Lesson Plans (RTP)

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Abstract

In recent years, Wyoming has developed Computer Science (CS) standards for adoption and use within K-12 classrooms. These standards, adopted in January of 2022, go into effect for the 2022-2023 school year. The University of Wyoming has offered two different computer science week-long professional developments for teachers. Many K-12 teachers do not have a CS background, so developing CS lessons plans can be a challenge in these PDs. This research study is centered around three central questions: 1) To what extent did K-12 teachers integrate computing topics into their PD created lesson plans; 2) How do the teacher perceptions from the two CS PDs compare to each other; and 3) How was the CS PD translated to classroom activity? The first PD opportunity (n=14), was designed to give hands-on learning with CS topics focused on cybersecurity. The second PD opportunity (n=28), focused on integrating CS into existing curricula. At the end of each of these PDs, teacher K-12 teachers incorporated CS topics into their selected existing lesson plan(s). Additionally, a support network was implemented to support excellence in CS education throughout the state. This research study team evaluated the lesson plans developed during each PD event, by using a rubric on each lesson plan. Researchers collected exit surveys from the teachers. Implementation metrics were also gathered, including, how long each lesson lasted, how many students were involved in the implementation, what grades the student belonged to, the basic demographics of the students, the type of course the lesson plan was housed in, if the K-12 teacher reached their intended purpose, what evidence the K-12 teacher had of the success of their lesson plan, data summaries based on supplied evidence, how the K-12 teachers would change the lesson, the challenges and successes they experienced, and samples of student work. Quantitative analysis was basic descriptive statistics. Findings, based on evaluation of 40+ lessons, taught to over 1500 K-12 students, indicate that when assessed on a three point rubric of struggling, emerging, or excellent - certain components (e.g., organization, objectives, integration, activities & assessment, questions, and catch) of K-12 teacher created lessons plans varied drastically. In particular, lesson plan organization, integration, and questions each had a significant number of submissions which were evaluated as "struggling" [45%, 46%, 41%]

through interesting integration, objectives, activities & assessment, and catch all saw submissions which were evaluated as "excellent" [43%, 48%, 43%, 48%]. The relationship between existing K-12 policies and expectations surfaces within these results and in combination with other findings leads to implications for the translation of current research practices into pre-collegiate PDs.[1]

1 Introduction

1.1 Motivation

As the world surges further into the 21st century society's reliance on computing and computer systems becomes more evident. To help addresses this growing dependency, the state of Wyoming has developed and released Computer Science (CS) standards in conjunction with a legislative mandate requiring all school districts to offer CS to their students by the 2022-2023 school year. However, many teachers around the state, and nation, have not been afforded the resources and scaffolding necessary to teach the content and materials that are covered within these new standards. Since it's been show that "exposure to engineering and other related fields such as science, mathematics, and technology greatly impact [students] career goals," [1] the last two authors at the University of Wyoming have increased their development and offering of Professional Developments (PD) to enable K-12 teachers to extend and broaden their abilities to bring CS to their students. These PDs include two funded by National Science Foundation grants (DRL Grant #1923542; CNS Grant#2055621), and another by the National Security Agency (H98230-21-1-0122). This paper provides an overview of the camps as well as the assessment of the PD's effectiveness at enabling K-12 teachers to implement CS topics in to their existing lessons and/or curriculum.

1.2 Wyoming CS Standards

As a means to address the lack of policy dictating pre-collegiate engineering education [2], the state of Wyoming's CS standards outline seven core CS practices that should be embedded within the curriculum and instruction [3]. Grade bands of K-2,3-5,6-8, High School level 1 and High School level 2 are identified within the standards and each has a defined set of content knowledge and skills that students are expected to know and be able to do upon by the completion of each grade band.

Presently, there is no easily adapted K-12 curriculum mapping to this set of CS standards - though there are several that have partial overlap with similar standards. This gap leaves K-12 teachers from across the educational spectrum, though especially in K-8, responsible for developing their own curriculum over CS topics covered within the standards despite their lack of explicit knowledge about the CS content which these standards cover. There is hope,

[1]This material is based upon work supported by the following agencies and grants: National Science Foundation (NSF) DRL Grant #1923542 "CS For All:RPP - Booting Up Computer Science in Wyoming," and NSF CNS Grant #2055621 "RET Site: WySTACK - Supporting Teachers And Computing Knowledge," and the National Security Agency (NSA) GenCyber #H98230-21-1-0122. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation or the National Security Agency.

however, in the fact that there is significant overlap in many of the underlying concepts in STEM and CS.

Below, the standards and specific learning outcomes are listed:

1. Fostering an Inclusive Computing Culture
   (a) Include unique perspectives of others and reflect on one's own perspectives when designing and developing computational products
   (b) Address the needs of diverse end users during the design and process to produce artifacts with broad accessibility and usability
   (c) Employ self- and peer-advocacy to address bias in interactions, product design, and development
2. Collaborating Around Computing
   (a) Cultivate working relationships with individuals possessing diverse perspectives, skills, and personalities
   (b) Create team norms, expectations, and equitable workloads to increase efficiency and effectiveness
   (c) Solicit and incorporate feedback from, and provide constructive feedback to, team members and other stakeholders
   (d) Evaluate and select technological tools that can be used to collaborate on a project
3. Recognizing and Defining Computational Problems
   (a) Identify complex, interdisciplinary, real-word problems that can be solved computationally
   (b) Decompose complex real-world problems into manageable sub-problems that could integrate existing solutions or procedures
   (c) Evaluate whether it is appropriate and feasible to solve a problem computationally
4. Developing and Using Abstractions
   (a) Extract common features from a set of interrelated processes or complex phenomena
   (b) Evaluate existing technological functionalities and incorporate them into new designs
   (c) Create modules and develop points of interaction that can apply to multiple situations and reduce complexity
   (d) Model phenomena and processes and simulate systems to understand and evaluate potential outcomes
5. Creating Computational Artifacts

(a) Plan the development of a computational artifact using an iterative process that includes reflection on and modification of the plan, taking into account key features, time and resource constraints, and user expectations
(b) Create a computational artifact for practical intent, personal expression, or to address a societal issue
(c) Modify an existing artifact to improve or customize it

6. Testing and Refining Computational Artifacts
   (a) Systematically test computational artifacts by considering all scenarios and using test cases
   (b) Identify and fix errors using a systematic process
   (c) Evaluate and refine a computational artifact multiple times to enhance its performance, reliability, usability, and accessibility
7. Communicating About Computing
   (a) Select, organize, and interpret large data sets from multiple sources to support a claim
   (b) Describe, justify, and document computational processes and solutions using appropriate terminology consistent with the intended audience and purpose
   (c) Articulate ideas responsibly by observing intellectual property rights and giving appropriate attributes

1.3 WyCS Hub

WyCS Hub is a digital resource for K-12 teachers around the state of Wyoming as well as around the country. Available on the hub are resources from previous PDs, including teacher-created lesson plans. In addition the resource includes the PDs that are offered and a place for K-12 teachers to sign up for future PDs. The WyCS Hub is a partnership between the College of Engineering and Applied Sciences and the College of Education at the University of Wyoming.

1.4 Research Focus

The focus of this research is to evaluate to what extent K-12 teachers can incorporate CS principles into curriculum after completing PDs. The proficiency of incorporation is evaluated based upon the analysis of three primary questions: to what extent did K-12 teachers integrate computing topics into their lesson plans, how do the teacher perceptions from the two camps compare against each other, and how was the PD translated to classroom activity. While the goal of the PDs is to provide K-12 teachers the tools, resources, and scaffolding needed to incorporate various CS topics into existing lessons within their classroom, an evaluation of what the K-12 teachers actually incorporate within their lessons will inform the PD developers/facilitators regarding their effectiveness in meeting their desired goal.

2 Related Works

Teacher PD plays a central role in ensuring that modern subjects manage to permeate the K12 educational ecosystem. When an K-12 teachers never had the opportunity to learn about a certain technology whether because their formal education occurred before the advent of said technology; because the technology had previously been prohibitively expensive; or because of other issues of equitable access to technology; often their only option is to pursue some form of PD. The variety in methodologies, modalities, and focuses of PDs has lead to a breadth of all three that has been studied previously in the literature. A brief survey of research on the topic of subject integration, the implementation of PDs, and the specifics of GenCyber and CSforAll programs are explored below.

2.1 Subject Integration

The integration of various subjects into PDs and further into the curriculum and lessons of a school are of interest when discussing the efficacy of PD modality. The interdisciplinary integration of Information and Communication Technologies (ICT) has been of widespread interest since the emergence of the digital age; and as a result, the form that technological integration takes in different fields can be examined before being extrapolated to integrating ICT into computing specific subjects.

2.1.1 Generalized Subject Integration

The desire to assess the integration of content presented through a teacher PD into the teachers' school is of great import. In fact, general guidelines for successfully communicating the role that PDs play in developing teachers' comfort with topics has been presented [4]. Others have examined ways that national or state standards can directly be translated into designed PD programs [5]. More specifically though, the integration of ICT into classrooms will continue to play a role of growing important as computing continues to become a critical skill for students to develop.

One way to conceptualize the study of integrating ICT into curricula is to consider it from the perspective of the K-12 teachers who seeks to implement the technological subject within the classroom. One of the largest hurdles for PD organizers to overcome is teachers core values about technology [6]. While many K-12 teachers may be intrinsically motivated to add technological aspects to their instruction, other analyses of adult learners suggest that it is necessary to address the underlying motivation for why ICT should be integrated into lessons [7]. PDs can serve the role of justifying motivation to teachers, ensuring that these subject make their way into lessons across varied classrooms.

Others recognize that the manner in which PDs address these concerns can further impact perceived ability to integrate ICT. Fostering teacher-led communities in which the agency and onus for development shifts over time from PD facilitators to K-12 teachers can result in more positive rates of ICT integration in classrooms [8].

Moving beyond K-12 teachers, the role that administrators, curriculum developers, and other educational staff play in the integration of ICT within curricula has an impact on the success of integration. PDs targeted at administrative staff, namely assistant principles, can lead to more successful integrations of ICT [9] within a specific academic community.

2.1.2 CS Subject Integration

More specific study on the integration of computer science topics and computational thinking have recently been explored. Beginning computing education before even using computers, the integration of "Unplugged" activities, offers a way for topics to be distilled to their core concepts and presented in simplistic ways that make topics as complex as cybersecurity accessible to students as young as elementary school [10]. One proposed model for PDs focused on computer science, called Exploring Computer Science, made use of long term, expert-led professional learning communities to positively affect teachers' ability and confidence related to implementing ICT topics into lessons [11]. This model was deployed exclusively in urban school districts in which traditionally under-represented groups were the majority. It was suggested that these learning communities would assist in forwarding the cause of equitable access to computing by engaging with these minority groups. Far more common though were one week long PDs; these events were most commonly a one-time experience targeted at in-service, high-school teachers during their summer break [12]. Finally, while it has been suggested that many K-12 teachers don't feel confident enough in using a tool to teach students about that tool, this can be remedied by integrating the technology into the PD directly [13]. Overall, various approaches to enabling K-12 teacher success in implementing CS subjects in the classroom have been explored with positive results. These methodologies go on to inform the approach to development of the PD presented throughout this work.

2.2 PD Implementation

The implementation of PDs may have the potential to further impact the integration of various ICT topics into course curriculum. The target audience of each PD might alter what PD developers consider to be the most effective modality, yet the underlying goal is always the same. Enabling K-12 teachers from all domain backgrounds to approach implementing the subject matter is the goal of many PDs. Burrows et al. found that key to successful implementation and reuse surrounds teacher and ultimately students to see the application, careers, and societal impacts associated with new subject matter[14] .

2.2.1 Generalized PD

The modality and implementation of PDs has been suggested to have an impact on the changes implemented by K-12 teachers undergoing said PDs. The exact ways these impacts manifest range from having reportedly little-to-no effect [15] to supporting the benefits of specific modalities [16]. Additionally, the underlying motivation for the structure of a PD may be able to impact the implementation of specific standards [17] or it may be used to directly instruct how to implement a specific curriculum in an attempt to market said curriculum program [18].

2.2.2 CS PD

The implementation of PDs in which computing topics play a central role continues to be studied as the integration of ICT becomes more relevant with each passing year; the development of the Advanced Placement (AP) Computer Science Principles (CSP) exam administered by College-Board led to a wide growth of interest in, and development of, computer science focused PDs. When the K-12 teachers engaging with a PD already have experience and desire to expand their integration of ICT, their perception of their learning and their intent to use knowledge and skills from a PD is high even when the PD encompasses large sample sizes of K-12 teachers (n=1138) [19].

Long term PDs – executed over the course of a full academic year – have also been studied as individual PDs and with a yearly cohort schema. The most effective way to engage with teachers on these extended periods is often to match teachers' computing backgrounds to the content being taught, to align the PD content with their specific curriculum needs, and explicitly motivate the PD content [20]. Due to the differing starting points of K-12 teachers, some possessing more formal backgrounds in computational thinking than others, each K-12 teacher is likely to learn and struggle with different levels of content [21]. Ensuring these requirements of varied and personalized PD are met has been suggested to improve the overall efficacy of a PD's implementation. Furthermore, post-PD support in various forms ranging from self-reflection notebooks [22] to contact with a CS undergraduate (as was implemented by the PD in this work) [23], can be critical to the success of the K-12 teachers. All of these cases, when considered in totality, illustrate the need for individualized, targeted PD that enables K-12 teachers to grow from whatever point they begin at and enables them to continue their development through self guided discovery and fellowship with other K-12 teachers over time.

2.3 Related Programs

In the pursuit of enabling PDs to address the growing need for computer science, and more specifically cybersecurity, education, the NSF and NSA, both of the United States of America, have developed programs to foster these PDs. GenCyber, a joint effort from both groups, and CSforAll, an undertaking of the NSF, both seek to address this need for pedagogical instruction relating to computing topics.

2.3.1 NSF/NSA GenCyber

The stated purpose of the GenCyber program is "to be a part of the solution to the US's shortfall of cybersecurity professionals by reaching kindergarten through 12th grade students and teachers, developing their awareness of cybersecurity and stimulating their interest in the cybersecurity field" [24]. In service to this end, the program allows for several different adoption models that may be assumed by each individual PD or camp team - typically comprised of faculty from a higher education institution. Each implementation, taking the form of a variable length PD or camp, often but not necessarily occurring during the summer, may present content to teachers exclusively, students exclusively, or some combination of teachers and students.

In addition to the flexibility provided in the form and participants invited to the PD or camp, the program allows for wide ranges in offered curriculum. Some camps prepare students for industry grade examinations, such as the Certified Ethical Hacker examination from the EC-Council[25] while other camps choose to present more foundational cybersecurity concepts [26]. This highlights the potential for vastly different content within the broader grouping of GenCyber, ensuring that the needs of K-12 teachers and students can be met regardless of their prior experience.

Results of camps can be quite striking, with their efficacy being measured in varied ways from one implementation to the next. One common method for analyzing the efficacy of a camp is the application of Pre- and Post-surveys. In some instances, though the majority of teachers in a teacher-exclusive camp had an increase in pedagogical understanding, some K-12 teachers experienced decreases in evaluation metrics drawn from these surveys [27]. Other camps showed strong increases in student's self-described ability to identify cybersecurity related concepts and their self-identified desires to pursue the field of cybersecurity in the future professionally [28].

Though the individual impact of any one camp can be largely dependent on the specific content covered, the target audience, and the methodologies employed by individual camp organizers, the NSF and NSA engage in evaluation intended to improve the quality and capability of organizers for subsequent years [25]. Taken in aggregate, the total efficacy of the program is well recognized and continues to be expanded year to year [24].

2.3.2 NSF CS for All

The United States national CS for All effort, led by the NSF and the Department of Education (DoEd) and in collaboration with other private and government agencies, aims to "ensure Computer (CS) education is available to all students in the U.S."[29] The initiative cites four key reasons why the effort is required, including: empowering students with computational thinking skills, addressing a critical workforce need, providing rigorous CS to all schools, and finally to expand access to under-represented groups within CS (e.g., "women, girls, minorities, and persons with disabilities"[29]).

For context, in 2018 28% of high school students taking the Advanced Placement (AP) CS exam self-identified as female despite females making up 55% of the overall cohort across all AP exam test-takers[30]. Some work has been done to address the need for PD that targets these under-served learning communities [31], but the need for inclusive computer science education clearly motivates the existence of the CS for All movement.

3 Methods and Analysis

To assess the impact of any individual PD, multiple differing methods and frameworks could be employed. The information presented to K-12 students must then be first implemented by K-12 teachers in lesson plans before students are even exposed to the topics. This disconnection, between subject matter experts and the K-12 teachers who directly interact with students, has the potential to obscure themes and concepts if not implemented appropriately. However, as discussed in §3.2, the rubric items applied to evaluating K-12 teachers lesson plans' implementations asks K-12 teachers to embed these topics into familiar subjects. Analyzing lesson plans enables the PD developers to reflect on and assess the efficacy of material presentation and the subsequent translation into lesson plans.

3.1 Research Questions

To ascertain the PD impact examined in this study, the following research questions are explored:

- RQ1: To what extent did teachers integrate computing and cybersecurity topics into their lesson plans?
- RQ2: How do the teacher perceptions from the two PDs compare to each other?
- RQ3: How was the PD translated into classroom activities by teachers?

The methods enumerated below in §3.4 correspond with the stated research questions.

3.2 Quantitative and Qualitative Data Collection

The quantitative methodology utilized two structures to evaluate teacher understanding of the subjects presented within the PD. First, Pre/Post-surveys were administered each day during the PD. These surveys asked multiple choice questions related to the cybersecurity content being presented during the day these surveys were administered. Each day the Pre-survey and Post-survey contained identical questions to accurately evaluate how teachers' understanding evolved over time as a result of their engagement with PD materials. Explicit answers were not provided to K-12 teachers during the course of instruction, but the K-12 teachers were encouraged to dwell on the questions throughout the day and use them to guide their exploration of the CS topics and themes presented during that day of PD. More details about the motivation and justification for the theoretical framework is presented in §3.3.

Secondly, additional quantitative data was collected to understand the makeup of the lessons which K-12 teachers implemented within their school communities. This data consisted of information about students, including their grade band and gender, as well as information about the lesson such as implementation date, length, and course name. This information is augmented with qualitative descriptions from K-12 teachers in the form of open-ended, text prompts. Questions asked in this section sought to gain an understanding of the teachers impression of the lessons efficacy by asking questions such as: what cybersecurity topics did you include; what was the purpose of this lesson; and did you meet the intended outcome of the lesson. Further questions then asked K-12 teachers for data and justification for their self-evaluations, allowing this work to examine how their perception of the lesson and its outcomes aligned with the intended outcomes described within submitted lesson plans.

Finally, qualitative data regarding teachers' beliefs about further lessons was collected. As in the previous qualitative questions asked, these took the form of open-ended text-prompts asking questions such as: How did you feel the lesson were delivered?; What would you change in the future?; and What aspects of the lesson were most successful or least successful? These questions, while not being directly related to the implementation of cybersecurity concepts allow for further exploration of RQ2.

3.3 Constructivist Theoretical Framework

The authors of this study applied quantitative methodology to the analysis of the PDs presented. The authors extended those quantitative findings using a qualitative theoretical framework and qualitative data collection. The implementation efficacy is analyzed through a constructivist framework that places emphasis on the need for establishing PD participant learning as a justified belief with the further assumption that instilling those K-12 teacher beliefs and their lesson plans are translated to K-12 students [32]. Educators were directed to activities to allow them to establish their own topic understanding before asking them to apply the topics to the creation of lesson plans.

The lesson plans K-12 teachers were asked to develop built upon their existing classroom schemata by tasking them with integrating cybersecurity concepts into lessons they would otherwise teach without the additional insight of said cybersecurity lens. As opposed to directly teaching computing and security subjects, this allows teachers to leverage their own understanding and justifications for the subjects' integration, giving them more "buy in" to the subject [33]. This internalized justification for the topic inclusion has been suggested to be correlated with the likelihood of an K-12 teachers integrating ICT topics into the classroom [7]. Thus, the PD focused on building that justification within K-12 teachers' minds through the engagement with activities and content.

3.4 Methods

Three methods are explored to answer the previously defined research questions; they combine the qualitative methods with the constructivist theoretical framework and relevant quantitative data to inform further analysis.

3.4.1 RQ1 - Extent of Integration

The collected lesson plans were further analyzed, along with any provided feedback from K-12 teachers, to assess as best was possible how well the concepts were translated from the PD to the class lessons. An external subject expert analyzed submitted lesson plans through the constructivist lens presented previously to analyze how well these lesson plans implemented the cybersecurity topics professed to be conveyed through the lesson. These lessons were then classified broadly into one of three categories: "struggling," "emerging," and "excellent" and further evaluated on the same scale for individual components, namely "organization," "objectives," "integration," "activities," "question strength," and "overall." These categories identified whether the cybersecurity concepts were presented in a manner that was "struggling to convey the specific topic through this lesson," "the topic's understanding is emerging through the lesson but still has room to be expanded upon," and "the content is portrayed in an excellent manner that clearly demonstrates the underlying cybersecurity topics" respectively. These evaluations were then interpreted as the extent of planned topic integration into the planned lessons.

3.4.2 RQ2 - Teacher Perception

Teacher perceptions were evaluated through the survey collecting data about lesson implementation. The development and use of these survey questions follows prior work of a similar nature and allows for future comparison and analysis between different teacher engagements (e.g., professional development, research experiences, etc.). Multiple questions, with various amounts of overlap were asked in an effort to ensure the full opinion of K-12 teachers on how the lesson went could be communicated to the research team.

These questions were:

- Explain how you would change the lesson when/if it is offered again.
- What were the challenges of implementing the lesson?
- What were the successes during the implementation of the lesson?
- What, if any, other comments or feedback that you would like to share with the team?

The research team then separated responses to these questions into the two K-12 teachers cohorts corresponding with the 2020 PD and 2021 PD. These responses are then contrasted to explore RQ2.

3.4.3 RQ3 - Classroom Translation of PD

To explore how the topics presented throughout the PD were translated into the classroom, the qualitative answers from K-12 teachers were further applied. Additional questions presented in the survey administered to K-12 teachers assessing their perceptions of the PD were analyzed through the described constructivist lens to determine to what extend the lessons from the PD were translated into the classroom in practice. These prompts were:

- What evidence exists to support whether or not the purpose of the lesson was met?
- Describe the data you collected about your lesson.
- Summarize the data that you collected about your lesson.

K-12 teachers were prompted to include the raw data they collected, enabling further post-analysis about the implementation of PD concepts into the classroom.

3.5 Analysis

The data analysis, including basic statistics and grouping of quotes, leads to a number of insights into the PD results. The qualitative findings, based upon the free-response survey questions given to K-12 teachers and interpreted through the described constructivist lens are discussed throughout §4 when these responses are relevant to the understanding of the research questions under consideration.

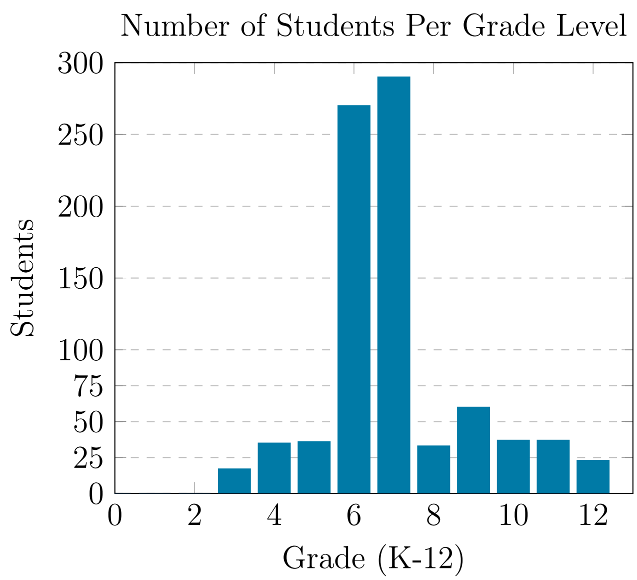

Figure 1: The number of students impacted per grade level

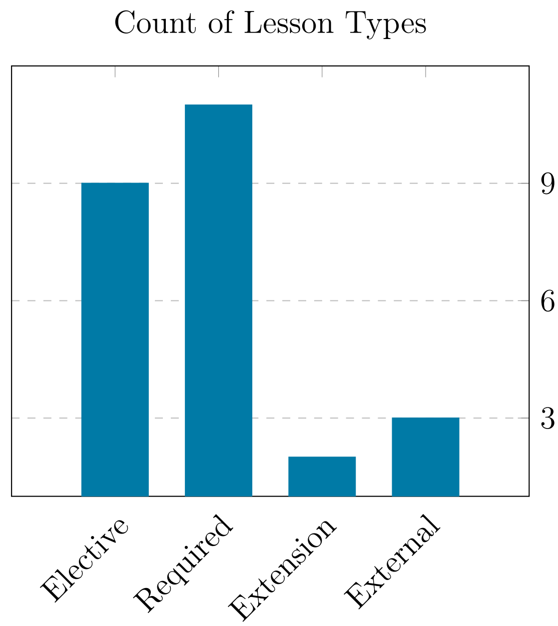

Figure 2: The type of class in which lessons were offered

4 Findings

Overall, a strong majority of lessons were taught in 6th and 7th grade classrooms and in classes specifically dedicated to the topics of computer science and computational thinking (see Figures 1 and 2). Students had a nearly even split between male and female (50% $\pm$ 0.3%) students with a small majority of female students across all classrooms.

The review category of submitted lesson plans identified 19.6% of plans to be "struggling," 32.6% of plans to be "emerging," and 47.8% to be excellent (presented in Figure 3). Further breaking apart the sub-categories lessons were evaluated upon, the average evaluation of a lesson plan in each category is presented in Figure 5. This figure was generated by assigning each lesson plan a value of 0 for "struggling" in a topic, 1 for "emerging," and 2 for "excellent." These values were then averaged to obtain the height for the graphs in Figure 5. Demographic data about the classrooms in which these lessons were delivered is presented in Figure 1 and Figure 2. In addition to the data presented in these figures, 50.3% of students were identified as female and 49.7% male. Finally, the count of lessons identified in each category – struggling, emerging, or excellent – is presented in Figure 4.

The specific findings of each research question are explored below. The implications of these findings beyond the specific GenCyber and WySlice PDs are explored in §5.

4.1 Extent of Integration

As is illustrated in Figure 3, a plurality of evaluated lessons plans were identified as "Excellent." While this illustrates a positive result for the integration of cybersecurity topics into the lesson plans, more granular analysis of the evaluation allow for discussion surrounding

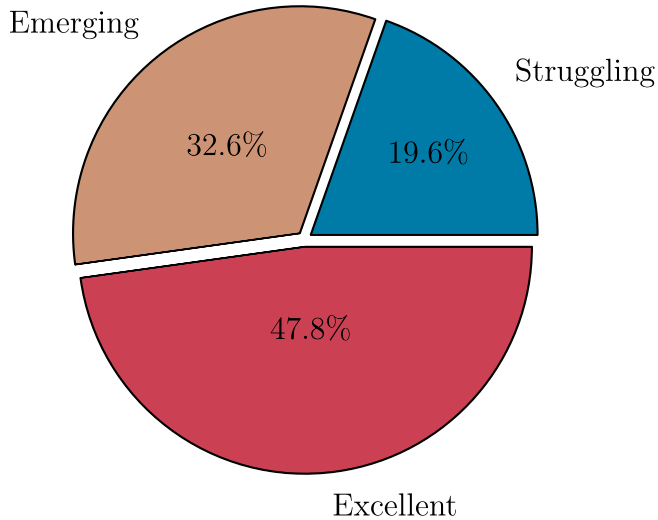

Figure 3: Overall Ratio of Evaluations

which aspects of a lesson plan may need improvement in the future. Central among the areas most needing improvement is the category of "Lesson Organization."

Only two of the evaluated lesson plans were identified as "Excellent" in the category of lesson organization. This result allows for future PDs to spend time directly addressing how to properly organize a lesson on computational thinking and cybersecurity topics. Other categories also had a plurality of "Excellent" evaluations, namely "Objectives" and "Activities." This mirrors the time spent in the PD well; most time was spent on teachers undergoing cybersecurity related activities and discussing learning objectives.

Perhaps most relevant to answering RQ1, the "Integration" category was polarized with only 5 lessons being evaluated as "Emerging" and all others being either "Excellent" or "Struggling." While many K-12 teachers were able to excellently integrate cybersecurity topics into their lesson plans, the disparity between evaluations on this topic demonstrate that more explicit instruction on integration may be beneficial.

Reviewer commentary over lesson plans evaluated as "Struggling" and "Excellent" in the realm of integration had common threads. Lesson plans that received evaluations of "Struggling" almost always contained reviewer commentary observing a lack of detail in the lesson plan itself or providing resources that were inaccessible to the review team. Whether this was a symptom of the K-12 teachers not understanding the subject (and therefore being unable to fully explain, articulate, and plan the lesson) or a symptom of the K-12 teachers simply creating a bare bones lesson plan (and therefore playing things by ear during the lesson) is unclear. Lessons evaluated as "Excellent" were almost always observed to tightly couple the lesson with specific standards, whether computer science or other subjects' standards, leading to an overall percentage of 47.8% lessons being "Excellent." Many of these lessons were developed and given in mathematics classrooms, leading to the further question of whether these lessons were successful because of the related nature of mathematics and computer science or some other factor accounted for the success.

Thus RQ1 is answered as "to varying extents." The extent to which K-12 teachers were

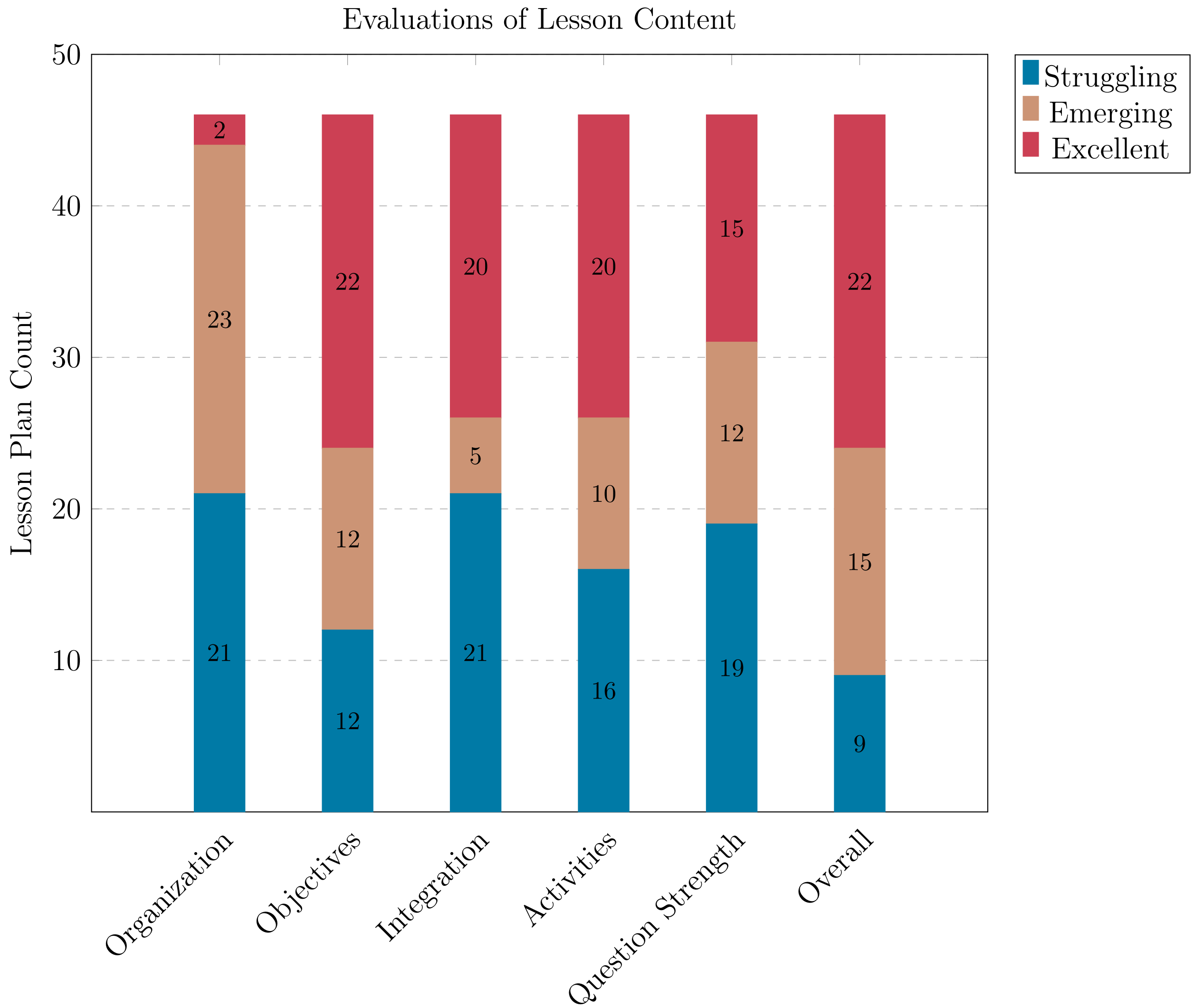

Figure 4: Number and Quality of Lessons Across Evaluation Areas

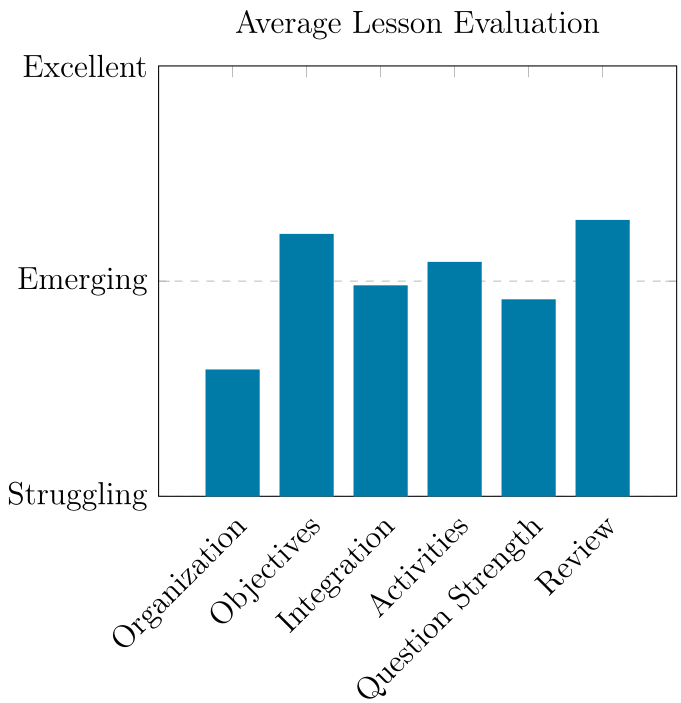

Figure 5: Average evaluation of lesson plans generated by assigning values of 0-2 associated with the struggling to emerging scale before averaging the values to obtain bar heights.

able to integrate cybersecurity topics varied. Additional work and data is necessary to understand if some underlying effect is responsible for the disparate levels of integration.

4.2 Teacher Perception

Despite the varying levels of evaluated integration, teachers' perceptions of the PD and their implemented lessons was largely positive. The first cohort (Summer 2020) identified a number of procedural problems with the PD itself while the second cohort (Summer 2021) identified issues more commonly related to the underlying content and lesson implementation. A common thread from K-12 teachers in the first cohort was difficulty knowing exactly what was expected of them each day during the PD. Since the Summer 2020 experience was intended to be at teachers own pace, with suggested activities each day, some had trouble distinguishing which assignments to complete each day and what to do if they fell behind the presented pace of the camp. The second summer, the PD made use of a more rigid layout of the LMS employed for delivering content. As a result, the concerns of teachers about what content to cover was decreased. Instructors, instead of simply being directed to work through content at their own pace were explicitly told on what days activities were planned to be covered. They were still encouraged to work on activities from previous days if they hadn't completed them in time, but the more rigid structure coupled with explicit instruction from PD developers to break that structure if they believed it would positively impact their engagement with the content led to fewer questions and concerns from K-12 teachers about what should be done and when it should be completed. Additionally, the content provided in the first year was likened to "drinking from a fire hydrant." A teacher described the experience as "a little too much, too fast and I didn't get it, which is frustrating because I like [sic] to get it." The changes to the curriculum the following year, including more strictly pushing a "basics" track instead of providing more free form decision between "basic" and "intermediate" tracks, coupled with the first day only presenting "basic" information alleviated these concerns for K-12 teachers in the second cohort. Teachers in that cohort still identified a quick pace to the camp, a necessity with the breadth of content needing to be covered in the camp, but found it far more approachable.

The largest challenge identified by teacher perception across both years related to circumstances surrounding COVID-19. While teachers had been exposed to cybersecurity topics throughout the camp, some said that, while they were still having troubles adapting their specific subject area to online learning, also adapting a topic they had only begun learning proved to be quite difficult. Other challenges across both groups of K-12 teachers related to devices. One teacher reported being unable to complete their planned lesson completely due to WiFi problems at their school. This lesson was adapted on the fly by the teacher and they still counted it as a large scale success due to "high student engagement." Limitations on the number of Micro:Bits possessed by teachers were also identified as challenges by teachers. Having students working in small groups and doing alternative, unplugged activities was the utilized workaround, but it was nevertheless a challenge in the implementation. Beyond these specific, technology-related problems, teachers identified problems that would be common across all subject areas: students not reading directions or instructions properly; students being behind if they missed a day; or time being more limited than the K-12 teachers anticipated.

Overall, RQ2 can be answered as "perceptions of the camp improved from one year to the next." This should largely be credited to the modified presentation of the curriculum since many of the curriculum resources (i.e. videos, activities, and handouts) remained constant from the first year to the second.

4.3 Classroom Translation of PD

The translation of PD topics into the classroom obviously is of much interest to the PD development team; understanding how topics are translated into the classroom from PD will inform future PD development. Throughout the evaluations of lesson plans, one clear theme emerges: the impact and outcomes of learning cybersecurity concepts as presented in the PD is lacking. Teachers, while being able to very strongly reproduce the content and some higher level discussion of the topic are also likely to struggle with connecting that topic to wider society and careers. This is understandable; one, week-long PD is obviously unable to properly provide a comprehensive cybersecurity education to K-12 teachers. While PD discussion brought in current events topics related to the cybersecurity topics being discussed (i.e. the Colonial Pipeline attack being discussed at the same time as the topic of ransomware), asking teachers to reach out and find those societal connections appears to be their largest struggle.

Beyond this struggle, lessons were evaluated to overall be good at integrating cybersecurity topics into classroom activities. Some lessons featured CS standards and concepts as secondary to other learning outcomes, but most managed to place cybersecurity, computer science, or computational thinking at a central point in the lesson. The problem previously discussed and identified in Figure 5 showcases that the lesson organization was lacking, and provides a clear avenue for improvement of future PDs developed using this model. The lesson plans that possessed the best evaluations were those that integrated mathematics and computer science. This lessons often came out of mathematics classrooms and leveraged the interconnection between computing and math.

Overall, lesson integration was good but had room for improvement. The struggle of this PD, getting disparate K-12 teachers up to speed on computational topics and then asking them to apply their newfound knowledge to lesson planning after only two or three days of instruction is obviously less ideal than a semester long course on the subject. K-12 teachers consistently said that they felt more empowered to teach these topics after the completion of the PD, but their integration of subjects can be improved. Future PDs will continue to iterate on the structure and form of the hands on learning sessions as well as resources and ideas provided to K-12 teachers post-PD in an effort to move more K-12 teachers from "Struggling" and "Emerging" to "Excellent" levels of integration.

5 Limitations

The primary limitation of this work is the small sample size of K-12 teachers undergoing the modality of PD described throughout this work. While the inclusion of multiple cohorts works to alleviate these concerns somewhat by spacing data collection out temporally, in addition to the future work discussed below in §5.1, further evidence may contribute to an evolution of the analysis over time. Section 5.2 delves into the specific implications of the findings currently identified within this work.

Another limitation is the secondary nature of some of the analysis. Since evaluation of RQ3 relies upon K-12 teachers self-describing the behavior they observed in the classroom, there may be some exaggerated benefits from their interpretation of events. They also aren't subject matter experts in the field of cybersecurity, so their evaluation of the translation may be different than an evaluation done by someone with more experience in the cybersecurity field. This limitation was attempted to be rectified by RQ1 and RQ2, as well as by examining RQ3 through the theoretical framework of constructivism as opposed to the quantitative data provided by K-12 teachers, but may still play a role in the findings supporting RQ3.

Additionally, the PDs as well as the data collection and evaluation still need some refinement, such as using valid and reliable data instruments. Other issues come from K-12 teachers self-reporting the K-12 student classroom engagement. Objective data is sometimes difficult to obtain for proper PD evaluation. The lesson plans also had issues with a lack of content, and it was hard to determine if this was a result of the instruction throughout the PD, or a lack of K-12 teacher content understanding for greater flexibility.

6 Conclusion

The goal of the offered PDs is to prepare K-12 teachers to be able to teach the new CS standards of Wyoming. The data would indicate that through the PD environments K-12 teachers are able to begin incorporating CS standards in to their lessons plans. The PDs were generally well received by K-12 teachers, with some refinements in year two, such as content being presented in the more structured LMS, the PDs were well received by the participants. The ability of the PDs creators to adapt to feedback and encourage K-12 teacher engagement and effectiveness is crucial to provide K-12 teachers with the best PD experiences possible. Ultimately the PD evaluation and continuation in to the classroom has been positive, but the data presented in this study shows room for continued improvement.

To accomplish the CS standards imposed by the state of Wyoming it is vital that K-12 teachers are able to correctly and effectively learn and convey computer science principles. Ensuring that the offered PDs are effective in giving K-12 teachers the tools necessary is essential. Proper evaluations and evolution based on this research will help to shape the PDs offered for years to come. Through reflective research the PDs can be improved upon each year, which in turn ensures that K-12 teachers are able to educate all their students properly and help better equip a generation for success in the digital world. While the camps offered at the University of Wyoming are developed with the state of Wyoming in mind; enrollment is open to K-12 teachers across the country. This approach extends the reach and the impact across the nation.

Future extensions of this work can explore more granular details surrounding the implementation of specific topics as identified by standards organizations and further examining these at the micro-standard level. It may continue by examining the relationship between PD developers, K-12 teachers, and students to each other and how PD modalities can be adapted to bring students directly into the process even in PD modes that occur in the traditional week long experience. Finally, future work may expand the concepts in this work to larger audiences to assess the ability of these works' findings to be generalized to various and diverse geographical, social, and economic environments.

References

[1] M. Riojas, S. Lysecky, and J. Rozenblit, "Educational technologies for precollege engineering education," *IEEE transactions on learning technologies*, vol. 5, no. 1, pp. 20–37, 2011.

[2] J. Chandler, A. D. Fontenot, and D. Tate, "Problems associated with a lack of cohesive policy in k-12 pre-college engineering," *Journal of Pre-College Engineering Education Research (J-PEER)*, vol. 1, no. 1, p. 5, 2011.

[3] A. Wilson, "2019 computer science content and 2020 performance standards with plds," [URL Blinded], 2019.

[4] K. L. McMaster, K. Baker, R. Donegan, M. Hugh, and K. Sargent, "Professional development to support teachers' implementation of intensive reading intervention: A systematic review," *Remedial and Special Education*, vol. 42, no. 5, pp. 329–342, 2021.

[5] M. Ghomi and N. Pinkwart, "Teacher professional development based on the digcompedu framework," in *ICCE-Int. Conf. Comput. Educ., Proc.*, 2020, pp. 689–691.

[6] E. Hixon and J. Buckenmeyer, "Revisiting technology integration in schools: Implications for professional development," *Computers in the Schools*, vol. 26, no. 2, pp. 130–146, 2009.

[7] S. L. Potter and A. J. Rockinson-Szapkiw, "Technology integration for instructional improvement: The impact of professional development," *Performance Improvement*, vol. 51, no. 2, pp. 22–27, 2012.

[8] T. J. Kopcha, "Teachers' perceptions of the barriers to technology integration and practices with technology under situated professional development," *Computers & Education*, vol. 59, no. 4, pp. 1109–1121, 2012.

[9] N. Abdul Razzak, "The effectiveness of a university-based professional development program in developing bahraini school leaders' management and leadership competencies of implementing effective school-wide professional development and ict integration," *Professional development in Education*, vol. 39, no. 5, pp. 732–753, 2013.

[10] R. E. Fees, J. A. Da Rosa, S. S. Durkin, M. M. Murray, and A. L. Moran, "Unplugged cybersecurity: An approach for bringing computer science into the classroom," *International Journal of Computer Science Education in Schools*, vol. 2, no. 1, pp. 3–13, 2018.

[11] J. Goode, J. Margolis, and G. Chapman, "Curriculum is not enough: The educational theory and research foundation of the exploring computer science professional development model," in *Proceedings of the 45th ACM technical symposium on Computer science education*, 2014, pp. 493–498.

[12] M. Menekse, "Computer science teacher professional development in the united states: a review of studies published between 2004 and 2014," *Computer Science Education*, vol. 25, no. 4, pp. 325–350, 2015.

[13] M. Borowczak and A. C. Burrows, "Ants go marching—integrating computer science into teacher professional development with netlogo," *Education Sciences*, vol. 9, no. 1, p. 66, 2019.

[14] A. Burrows, G. Wickizer, H. Meyer, and M. Borowczak, "Enhancing pedagogy with context and partnerships: Science in hand," *Problems of Education in the 21st Century*, vol. 54, p. 7, 2013.

[15] B. Fishman, S. Konstantopoulos, B. W. Kubitskey, R. Vath, G. Park, H. Johnson, and D. C. Edelson, "Comparing the impact of online and face-to-face professional development in the context of curriculum implementation," *Journal of teacher education*, vol. 64, no. 5, pp. 426–438, 2013.

[16] Z. Yurtseven Avci, L. M. O'Dwyer, and J. Lawson, "Designing effective professional development for technology integration in schools," *Journal of Computer Assisted Learning*, vol. 36, no. 2, pp. 160–177, 2020.

[17] S. Jenkins and J. J. Agamba, "The missing link in the ccss initiative: Professional development for implementation," *Academy of Educational Leadership Journal*, vol. 17, no. 2, p. 69, 2013.

[18] C. B. Crowley, "Professional development as product implementation training," *Teaching and Teacher Education*, vol. 67, pp. 477–486, 2017.

[19] S. Murthy, S. Iyer, and J. Warriem, "Et4et: A large-scale faculty professional development program on effective integration of educational technology," *Journal of Educational Technology & Society*, vol. 18, no. 3, pp. 16–28, 2015.

[20] Y. Qian, S. Hambrusch, A. Yadav, and S. Gretter, "Who needs what: Recommendations for designing effective online professional development for computer science teachers," *Journal of Research on Technology in Education*, vol. 50, no. 2, pp. 164–181, 2018.

[21] P. J. Rich, S. L. Mason, and J. O'Leary, "Measuring the effect of continuous professional development on elementary teachers' self-efficacy to teach coding and computational thinking," *Computers & Education*, vol. 168, p. 104196, 2021.

[22] M. Ukrop, V. Švábenskỳ, and J. Nehyba, "Reflective diary for professional development of novice teachers," in *Proceedings of the 50th ACM technical symposium on computer science education*, 2019, pp. 1088–1094.

[23] S. Sheridan, C. Mouza, and L. Pollock, "Professional development for computer science education: design and outcomes from a case study teacher," in *Society for Information Technology & Teacher Education International Conference*. Association for the Advancement of Computing in Education (AACE), 2019, pp. 1115–1123.

[24] T. Ladabouche and S. LaFountain, "Gencyber: Inspiring the next generation of cyber stars," *IEEE Security & Privacy*, vol. 14, no. 5, pp. 84–86, 2016.

[25] B. R. Payne, T. Abegaz, and K. Antonia, "Planning and implementing a successful nsa-nsf gencyber summer cyber academy," *Journal of Cybersecurity Education, Research and Practice*, vol. 2016, no. 2, p. 3, 2016.

[26] S. Wolf, F. P. Moss, R. Manandhar, M. Cooley, R. Cooley, A. C. Burrows, and M. Borowczak, "Building collaboration and securing interest in computer science education through outreach opportunities," in *2019 ASEE Annual Conference & Exposition*, 2019.

[27] K. M. Thomas, J. Ivy, K. Cook, and R. Kelley, "The impact of a gencyber camp on inservice teachers' tpack."

[28] S. Wolf, A. C. Burrows, M. Borowczak, M. Johnson, R. Cooley, and K. Mogenson, "Integrated outreach: Increasing engagement in computer science and cybersecurity," *Education Sciences*, vol. 10, no. 12, p. 353, 2020.

[29] "Computer Science is for All Students! - Special Report | NSF - National Science Foundation." [Online]. Available: https://www.nsf.gov/news/special$_reports/csed/csforall.jsp$

[30] K. Lim and C. M. Lewis, "Three metrics of success for high school csforall initiatives: Demographic patterns from 2003 to 2019 on advanced placement computer science exams," in *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, 2020, pp. 598–604.

[31] A. Hutchison, J. Colwell, K. Gutierrez, A. Evmenova, J. Offutt, and V. Taylor, "Designing a model of computer science professional development for elementary educators in inclusive settings," *Journal of Technology and Teacher Education*, vol. 29, no. 2, pp. 165–193, 2021.

[32] E. J. Hyslop-Margison and J. Strobel, "Constructivism and education: Misunderstandings and pedagogical implications," *The Teacher Educator*, vol. 43, no. 1, pp. 72–86, 2007.

[33] D. C. Phillips, "The good, the bad, and the ugly: The many faces of constructivism," *Educational researcher*, vol. 24, no. 7, pp. 5–12, 1995.