A Hermeneutic Phenomenological Project Exploring The Adoption of Cybersecurity Into Liberal Arts Computing Programs

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By

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Figure 1

Love for Computing

Note: The researcher's programming attention span remains approximately the same.

The University of Jamestown faculty, administration, and Computer Science and Technology department faculty also greatly supported completing this doctoral program. Erik Sand, Mary Reed, and Kathryn Lemm – from instructors to colleagues, mentors, and friends, it

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Abstract

This project examined the adoption of cybersecurity into computing programs within liberal arts programs and whether the rate constitutes an innovative program. The research questions focused on the lived experience existing faculty members have had with the cybersecurity curriculum within liberal arts computing programs. Liberal arts general education requirements were also examined to determine whether or not cybersecurity content has extended beyond individual programs and is part of a holistically developed student. As part of this project within liberal arts institutions, computing programs did not have explicit cybersecurity programs, but dominant themes emerged from the project. The primary themes of curriculum development, cross-discipline, and flexibility were well rooted in literature. However, the most surprising and significant findings were the themes of mission and values and semantics and terminology. The project concluded that addressing cybersecurity curricular content from a definitive baseline was an incorrect question. The right question was figuring out how a program's identity tied into the institutional mission and values and then selecting the appropriate curriculum recommendations from third-party organizations that fit, ensuring the best possible outcome for students in liberal arts computing programs based on the institutional mission and values. The project's findings also recommended developing a process for selecting and utilizing baseline curricula recommendations from organizations such as the ACM/IEEE groups in a liberal arts context.

Table of Contents

List of Tables

List of Figures

Chapter One

Introduction

Overview

When evaluating the curricula found within liberal arts undergraduate computing programs, there are three aspects to consider: purpose, content, and context (Detweiler, 2021). Detweiler (2021) expanded that definition to the intended outcomes, what was studied, and the environment in which it took place. In attempting to define the elements around a specific aspect of context, namely cybersecurity within liberal arts programs, it was essential to consider the factors around that clear focus. These programs were typically small, with only three faculty as the mean figure for programs self-identifying as liberal arts computing programs (Teresco et al., 2022). Understanding the faculty experience working within liberal arts computing programs provided insight into the curricular development process of how undergraduate educational programs. That further clarified the structure and what guidelines curricula may or may not have formed the basis of those programs.

An explicit purpose of looking at the curricular content of undergraduate students resided in the students who completed computing programs becoming future professionals in computer science, information technology, and related fields. As such, this project looked at liberal arts computing programs and the faculty who teach and facilitate the design of those programs to determine if any utilization of baselines or references when deciding on curricular content at a programmatic level. Additionally, the project looked at the lived experience of the faculty, which resulted in discovering the current state and goals of computing programs within a liberal arts institutional setting and looking at the adoption rate and extent of cybersecurity in those programs. The constraint of resources in liberal arts computing programs was typical, with the number of faculty being limited and the number of students being lower than institutional types with a greater enrollment basis (Teresco et al., 2022). Both the literature and project demonstrated that it was often a scenario that faculty will teach one or more courses that are not within their experience or direct education or oversee a program that contains courses outside their direct experience or education. Walker (2019) described this as an issue of breadth versus depth. It was, therefore, likely that faculty with limited or differing qualifications would have made curricular content decisions, at least when compared to faculty with direct experience or education in that topic area. It was an issue for individuals to know what guidelines or references to utilize for their course or program and the degree to which programs follow those guidelines. Those guidelines and references became essential for program implementation or revision through university governance processes.

Preparation for the program and student outcomes and attempting to define at a program level whether appropriate preparation for life after completing undergraduate education aligns with the institutional goals was an open question. Therefore, the project looked at the faculty experience with curricular content. The critical indicator for determining whether a program constituted as innovative was to what extent cybersecurity was a topic of the curricula found within those programs. The expansion of this was the historically used curriculum on standards developed by governmental agencies, professional organizations, or educationally affiliated groups. Identifying what faculty have experienced to date helped to establish what elements may or may not be relevant when evaluating a liberal arts institution's computing program.

To address the terminology around programs in the liberal arts that were the focus of this project, which could constitute computer science, information technology, or related disciplines, and educational approaches found within this project, the overarching term of *computing* was applicable in this context. This project first defined what constitutes a liberal arts program, liberal arts computing programs, pedagogy, cybersecurity as a discipline, and curricular guidance. An extensive literature review revealed many different descriptions and definitions of what constitutes the liberal arts and long-standing trends attempting to define or support the inclusion and integration of a computing program within that liberal arts context. With those varying opinions and trends, clarity in what comprised cybersecurity program content within those liberal arts computing programs was inconsistent and unclear. Moreover, the multitude of potential program reference points developed from the literature led to confusion of choice. That confusion of choice led to difficulty providing justifications for institutions when presenting, submitting changes, aligning or developing outcomes, or creating new programs. Conversely, the choices available and the smaller department size empowered faculty within those departments to analyze what they have been teaching and how it did or did not fit their program (Teresco et al., 2022).

Background and Problem Statement

When conducting curricular development or review, there were many potential reference points that faculty could have used in the past or selected to use in the future. To establish what faculty have experienced in resolving this issue, adopting cybersecurity curricular elements in liberal arts computing programs was the topic for this dissertation. Liberal arts institutions often had a different focal point for their programs than technical colleges, boot camps, or larger research-oriented counterpart institutions (Baldwin, 2018). While curricular guidance existed regarding the cybersecurity curriculum, there was very little in integrating cybersecurity into the unique opportunities that liberal arts computing undergraduate programs provide (Cyber2yr2020 Task Group, 2020; Joint Task Force on Cybersecurity Education, 2017). The closest reference point was the overall computer science-orientated curricular guidance, including cybersecurity elements (Joint Task Force on Computing Curricula, 2001). In the specific context of liberal arts computing programs, the ACM/IEEE guidance has historically been issued responses from the Liberal Arts Computer Science Consortium (LACS) to make those guidelines more applicable to liberal arts programs (Walker, 2018). However, the last curricular response from LACS was in 2007, and no new curricular guidance documents have originated from the LACS group since then (Liberal Arts Computer Science Consortium, 2007; Walker, 2018). According to D. Reed, engagement from LACS took the place of working directly with the committee in developing the computer science guidelines released in 2013 (personal communication, June 14th, 2022).

Therefore, the first research question explored how current liberal arts computing programs have adopted cybersecurity content into their computing programs to date in order to address the current state of these programs using cybersecurity and whether or not those programs constituted as innovative by utilizing the Diffusion of Innovation (DOI) theory. While being more subjective, the second research question established whether or not cybersecurity had been adopted into liberal arts general education requirements found at the institutions of the faculty participating in the project and not just within computing programs. Exposure to cybersecurity concepts was a presumption of a holistically developed modern undergraduate student. As Mountrouidou et al. (2018) demonstrated, literature existed on the inclusion of cybersecurity in general education requirements. However, the project located literature on cybersecurity outside the liberal arts context, and it became relevant to compare with the context of the project.

The conclusion of the wide variety of curricula submitted to the SIGCSE Liberal Arts committee was that there is no unified basis for programs to utilize for program development or refinement with varying definitions and recommendations (Teresco et al., 2022). Whether or not such a unified basis was desirable for the institutional type remained a gap within the literature. With the cross-discipline focus of this institutional type, some baselines' intended applications facilitate institutional outcomes such as Higher Learning Commission (HLC) accreditation or other relevant accrediting body (Ward, 2021). Research-based institutional program justifications were critical to curricula justifications in those program development or revision initiatives. The basis of justification was that individual faculty are making those program decisions that may or may not have specific experience with all of the topics in their programs (D'heedene, 1982; see also Walker, 2018).

Cybersecurity was utilized as the exemplar of a newer independent academic discipline to examine the lived experience of faculty who have been in the position of liberal arts computing program development and instruction. The entire purpose of undergraduate education, specifically in philosophical viewpoints such as liberal arts, was that of a competently educated student who has met the desired outcomes of their chosen background (Detweiler, 2021). Therefore, researching the lived experience of the faculty producing these graduates explored whether or not programs were innovative in adopting cybersecurity within their programs.

Curricula Justification

Releases on curricular guidelines concerning cybersecurity in undergraduate programs have been relevant to computing programs. However, application in a liberal arts institutional setting has been limited for educators in liberal arts computing programs to utilize (Joint Task Force on Cybersecurity Education, 2017). Mountrouidou et al. (2018) attempted to develop a framework known as the Cyberpaths project. Still, there has been no follow-up research to see how other institutions have integrated cybersecurity into their curricular efforts.

The closest recent development in the area has been a comprehensive look at computer science curricular innovations in liberal arts institutions. Teresco et al. (2022) felt that those recent developments still do not directly address the cybersecurity aspect as an independent field or potential undergraduate major. The resultant approach looked at the broader field of computer science within the liberal arts to attempt to draw comparative conclusions about the current state of curricula development. This project utilized the term *computing* to generalize the multiple disciplines and sub-disciplines, such as information technology and cybersecurity, that may or may not be present in a liberal arts program.

In broadening the literature review from one specific study, the various undergraduate curricular guidance documents presented potential applications for the composition of undergraduate cybersecurity programs. The ACM/IEEE CC2020 Task Force (2020) report on curricular guidance has been one of the core reference areas for structure in computing programs. The report presented how curricular guidance documents have changed over the years and explained the relationships between the various computing-related disciplines (CC2020 Task Force, 2020). However, with the cybersecurity guidance only coming out in 2017 and the general report on curricula in various computing fields such as computer science, information technology, cybersecurity, and computer engineering, being revised and released in 2020, much of the literature published on those guidelines and their implementation was incredibly new (CC2020 Task Force, 2020; Joint Task Force on Cybersecurity Education, 2017). The ACM/IEEE joint task force was already working on a new version of the computer science curricula and, as part of that, stated that it was in the process of reviewing what should be considered core security concepts versus cybersecurity curricula along with looking to engage as many of the potential users of the documents as possible (Kumar & Raj, 2022).

Those recent revisions mean that there are presumably many implementations of cybersecurity courses in undergraduate programs based on various outcome goals for existing programs. The resulting gap in the literature led to a failure to understand how and why institutions have done whatever they have to facilitate future liberal arts students' needs in cybersecurity and the outcome of a holistically developed individual. The project explored the current state of cybersecurity curricula by analysis of the lived experience of faculty working within computing programs and the level of integration with the broader undergraduate liberal arts curriculum.

This project focused on adopting cybersecurity into liberal arts institutional programs by exploring the lived experience of liberal arts computing program faculty who have designed or taught courses within such a program. A core of this project was a greater insight into liberal arts institutions' beneficial elements while providing research-based justifications for current or future program development. Liberal arts institutions, and even more specifically, members of the ACM SIGCSE Committee on Computing Education in Liberal Arts Colleges, or SIGCSE-LAC, were the core audience for the research and the pool of research participants. The committee has historically met in conjunction with the annual SIGCSE Technical Symposium, or SIGCSE-TS, as an affiliated event to foster collaboration, understanding, and communication between faculty members interested in liberal arts and computer science education.

Significance of Project

Historically, the primary method of collecting information on the implementation of curricula at a range of institutions has been to analyze course catalogs from several institutions has been quantitative studies based on course catalogs. Previous studies have explored numbers, programs, and highly defined questions on objectives, outcomes, and terminology (Abu-Taieh, 2017; see also Blumenthal, 2022b). This project aimed to understand the facultys' justifications better and lived experiences by taking a phenomenological qualitative approach. Justifications presented themselves via that understanding, giving richer insight into usage and actual application of what guidelines exist.

While there was consideration to qualitative and quantitative approaches, as there were very few information technology theories to utilize, and the project itself is a blend of computer science, cybersecurity, liberal arts, ethics, philosophy, and pedagogy, a qualitative approach was selected. The approach allowed for a much more dynamic and impactful project. New developments such as postphenomenology focusing on blending the philosophy of technology with phenomenology were considered a possible approach. However, this approach was deemed inappropriate for an initial project focusing on the human experience with a technical subject versus the human experience with technology (Ihde, 2009). Explaining reasoning and justifications behind a selection of institutions provided the larger body of liberal arts institutions with essential elements in formulating their curriculum planning and reasons for proposed content, revisions, and structure.

Nature of Project

This project considered both quantitative and qualitative approaches to the research design. The information sought by conducting the project is highly variable, with the specific topic of adopting cybersecurity into liberal arts computing programs. Quantitative research was deemed inappropriate. Quantitative surveys would have been extremely limiting in the scope of potential data collection and thereby skew the analysis toward experimenter bias (Peoples, 2021). Additionally, there were anticipated aspects of the findings, such as a representative look at the current state of cybersecurity in liberal arts computing programs and additional intended revelations into justifications and approaches. A qualitative project allowed for the design flexibility to better explore and document the practice and lived experience of the participants while providing a structure for the data collected (Peoples, 2021).

Different qualitative studies were also considered, such as Case studies, Ethnography, Grounded Theory, and Phenomenological (Creswell & Poth, 2017). The selection of phenomenology was the best fit for this project on adopting cybersecurity into liberal arts computing programs. While phenomenological studies can be very different from other qualitative methods, answering how individuals experience a specific phenomenon was the core of the approach (Peoples, 2021). The other forms of qualitative studies either looked at existing material, would have missed digging into the justifications of why something was how it was, or failed to explore appropriately captured bias that may be present in the project or the subjects.

At the same time, there have been newer developments, such as postphenomenology, focusing on blending technology's philosophy with phenomenology enhancing the theory involved with modern technological developments (Ihde, 2009). Ihde (2009) proposed an approach that mostly refuted the supposed romanticism associated with Heidegger and focused on blending hermeneutics, pragmatism, and phenomenology (Coeckelbergh, 2020). Zwier et al. (2016) provided further criticisms and support for the rejection of postphenomenology in the literature and discussed that its empirical nature precludes phenomenological questioning.

Two prevailing types of phenomenological research were reviewed and considered for use as grounding philosophies: Edmund Hussler with transcendental phenomenology and Martin Heidegger with hermeneutic phenomenology (Heidegger, 1971; Husserl, 1931). The theoretical framework significantly impacted the project in selecting this qualitative methodology. In a phenomenological project, the theoretical framework is always phenomenology (Peoples, 2021).

Hermeneutic phenomenology explicitly supported the usage of lenses to view the project to enhance one's understanding of the phenomenon (Peoples, 2021; see also Gadamer, 2004). The definition of lenses was that of enhancements or changes in support of the underlying viewpoint (Peoples, 2021). The secondary lenses utilized in this project are the technology-related frameworks expanded upon in the theoretical framework section and literature review and are traditionally considered the theoretical framework, which is why phenomenology was the grounding framework and used the term lens for the supporting framework.

Peoples (2021) stated that bracketing is the primary approach in transcendental phenomenology, where there is a suspension of judgment to focus on analyzing the experience. The debate still existed on the approach to bracketing carefully as Husserl's definition, and a comparison with Heidegger showed a slightly different interpretation (LeVasseur, 2003). LeVasseur (2003) looked at the definition of bracketing and the emphasis on the study of essences. Heidegger's shifted toward the study of being (LeVasseur, 2003). The study of being was why hermeneutic phenomenology was selected. Heidegger believed that bracketing was not possible because the researcher is part of the world or phenomenon that is the subject of study (Peoples, 2021). He branched off from Husserl's use of bracketing and intentionality and focused on *Dasein*, meaning being there, as it was impossible to completely separate oneself from the world (Peoples, 2021). That does not translate as bias as being acceptable but inevitable. As opposed to strictly bracketing, the revisionist process worked on accounting for and reducing the impact of bias. It did this by modifying the elimination to factor that being there may introduce bias and, through the revision process, worked to eliminate or reduce that bias (LeVasseur, 2003).

Heidegger (1971) resolved this through the hermeneutic circle, which philosophically viewed research as a revisionary process. Heidegger (1971) encouraged the capture of preconceived knowledge, which he called *foresight*, after which data is captured and analyzed. Usage of *foresight* develops an understanding that is then analyzed and interpreted and where the term circle originated in the hermeneutic circle. That circle was the core of what Heidegger viewed as interpretation: a state of constant revision and refinement (Peoples, 2021). Additionally, making personal biases explicit was necessary for this approach. Journaling was typical of the hermeneutic circle (Peoples, 2021).

The journalling approach allowed the development of an understanding of the lived experience of the participants while viewing the project through the most appropriate grounding philosophy or theoretical framework that revised interpretations developed. Capturing that lived experience provided additional insight into the central research question for this project that would have been difficult, impossible, or overly constrained by studies of a quantitative nature or grounded in different qualitative methodologies.

The primary participant pool was a selection of twelve participants from a minimum of four different liberal arts institutions intended to be a mixture of faculty and curricular designers while also accounting for occasionally combined roles. Whether or not the participants fit a particular role, the interview questions gave insight into the lived experience with cybersecurity in their curricular program as it pertained to developing or teaching. It required more institutions to meet a minimum of twelve participants. There was no limit on the number of unique institutions included in the project to ensure enough interviews of unique individuals. The participants were selected from respondents to a solicitation to the SIGCSE Committee on Computing at Liberal Arts Colleges Listserv, the SIGCSE-TS affiliated event, and the SIGCSE-

Members Listserv. Recruitment continued past the initial twelve participants to balance roles and the number of institutions and allow for attrition or withdrawal of participants to ensure the completion of a minimum of twelve participant interviews. The final participant count met the goal of having twelve participants. Additional attempts to track down the remaining signups that had not completed an interview failed, but there was no additional recruitment of participants after the pilot test, and twelve initially selected participants completed the pre-interview survey. Finally, no further solicitations to the Listserv or snowball recruits occurred after that point.

Research Questions

The research questions were semi-structured in that they were open-ended and subject to interpretation by the participants. Primary and probing questions allowed for flexibility in the participants' answers. All questions directly related to the central research question of how cybersecurity had been adopted or implemented in liberal arts computing programs. Through the questions, a developed understanding of the type of programs emerged. The project explored further the basis of those programs and the perceived level of flexibility found in those programs. The semi-structured nature further enabled participants to narrate their experiences, revealing the studied phenomenon (Dibley et al., 2020). The primary objective was to guide the discussion and bring it back to the associated questions when it was reasonably possible to do so. It also allowed for the exploration of unanticipated topics that presented themselves.

RQ1:

Compared to the growth of the cybersecurity academic discipline, what was the lived experience of faculty in liberal arts computing programs with the adoption of cybersecurity concepts into liberal arts computing programs, and could the degree or rate of integration constitute an innovative program?

RQ2:

Compared to the growth of the cybersecurity academic discipline, what was the lived experience of faculty in liberal arts computing programs when adopting cybersecurity concepts into liberal arts institutional programs outside of dedicated computing programs demonstrating overall innovation and cross-disciplinary education?

Theoretical Framework

The theoretical framework selected for this project as the primary lens to view research was the Diffusion of Innovation Theory (DOI). The theory explains how, why, and at what rate innovations grow within particular areas. The grounding framework was hermeneutic phenomenology (Peoples, 2021). The DOI was well established as one of the foundational social science frameworks (Rogers, 1962). An example of the DOI theory would be the rate at which the general public adopted the iPhone after its initial release in the mid-2000s.

As the initial framework for the project, the DOI provided a framework for guiding the project in the approach to asking the research questions. Prescott (1995) expanded the DOI and enhanced its applicability in the application of information technology researchers, which assisted in relating the DOI to technologically related research. Developed by Rogers (1962), the DOI breaks down the innovation population into five different groups based on their adoption of that innovation: innovators (first 2.5%), early adopters (next 13.5%), early majorities (next 34%), late majorities (next 34%), and laggards (the final 16%). The distribution of these groups typically followed a bell curve. Whether or not adopting cybersecurity into liberal arts computing programs was the specific innovation studied. It also provided insight into the experiences of the project participants, as the participants' responses will be a perception of how their institution rates the rate of innovation concerning curriculum development.

Furthermore, the DOI influenced the utilization of new material within the classroom (Jwaifell & Gasaymeh, 2020). The project on adopting new material demonstrated that adopting an innovation will result in more adoption of future innovations in the classroom. Cybersecurity was a prime example of such innovation as an outgrowth of the original academic discipline of computer science.

Limitations of the Project

The scope of this project was limited to liberal arts institutions. However, those institutions may or may not have defined computing degree programs within those institutions. While the solicitation was via the Listserv, utilized was a pre-interview survey to ensure the minimum number of institutions. Additionally, the pool of participants was a minimum of twelve to sixteen individuals from a minimum of four institutions. A final limitation was relying on the snowball recruitment method for a portion of the participant pool. While no evidence of skewing presented itself, that methodology can be susceptible to generating a skewed sample population.

The primary delimitation for this project was to limit the participant pool to members of the ACM SIGCSE Committee on Computing Education in Liberal Arts Colleges listserv and the broader SIGCSE-Member listserv mailing.

The project's resulting limitations are the makeup of the participant pool and the population size. Many institutions consider themselves liberal arts but may not have participated in the ACM organization on an institutional or individual professional basis, based on the number of unique institutions represented in the SIGCSE liberal arts listserv and the overall number of institutions identify themselves as being liberal arts. Another limitation was that specific role definition at the institutions of the liberal arts participating in the project, differentiating between instructors and curriculum designers, was not possible as all participants indicated a combined role in their institution. Finally, recruiting more than one participant from each institution proved highly challenging. While not a limitation in the strictest definition of the word, it required noting that according to Teresco et al. (2022), liberal arts institutions often had smaller departments, which made it rare to gain more than one participant per institution.

Notwithstanding the delimitations and limitations, generalizability in the resultant data certainly exists. As the literature indicated a strong trend towards cross-discipline initiatives, those types of education are typically considered a primary factor of a liberal arts education. The logical outcome was that a phenomenological project on curricular implementation could apply to non-ACM-affiliated liberal arts institutions and potentially even computing programs found within non-liberal arts institutions.

Assumptions

With this project, there were minimal assumptions, but essential aspects of the project exist that can only be assumed and not established as fact (Peoples, 2021). The most central assumption was that the participants answered truthfully and fully each of the research questions. The central assumption led to the second assumption that the implementation or integration of cybersecurity concepts or curricula has already happened within the institution's programs to some extent. Finally, there was an assumption that a broad number of unique institutions represented by participants enhanced the collected data instead of skewing the data.

Definitions

Internet of Things: Network connection of everyday objects has arisen in many new technologies, such as embedded systems and hyper-connectivity (Palmaccio et al., 2021).

Cybersecurity: "Cybersecurity includes physical and non-physical security of data, software, and hardware from harm by authorized and non-authorized access, whether access is internal or external" (Abu-Taieh, 2017, p. 104).

Information Assurance: The operations that protect and defend information and information systems to ensure availability, integrity, authentication, confidentiality, and non-repudiation (Utakrit & Utakrit, 2021).

Computational Thinking: "Computational Thinking is about searching for ways of processing information that is always incrementally improvable in their efficiency, correctness, and elegance" (Li et al., 2020, p. 4).

Liberal Education: "Liberal Education is an approach to undergraduate education that promotes the integration of learning across the curriculum and co-curriculum, and between academic and experiential learning, in order to develop specific learning outcomes that are essential for work, citizenship, and life" (Association of American Colleges & Universities [AAC&U], n.d.).

Summary

Hermeneutic phenomenology was the approach in conducting this qualitative research project. The project documented, interpreted, and revised the participants' conveyance of their lived experiences in liberal arts and the adoption of cybersecurity curricula into the programs they had experienced. That experience gave insight into how undergraduate programs differed in curricular content. Furthermore, through that lived experience, the reasoning for differences between programs was explored. The project helped establish the purpose, content, and context (Detweiler, 2021).

In attempting to define the elements around a specific aspect of context, namely cybersecurity within liberal arts programs, the lived experiences of faculty helped establish a clearer view of that purpose, content, and context. The project findings facilitated research-based evidence and justifications for how cybersecurity topics have been implemented and adopted at liberal arts institutions. That evidence provided information for similar institutions to review, update, or create computing programs with critical reference points rooted in literature. Using the findings as a comparison point for determining the rate of innovation at a given institution proved to be more difficult than anticipated. Finally, programs will be able to evaluate curricular guidelines in a process-based fashion to the degree to which cybersecurity makes sense for their liberal arts-based computing program. The literature demonstrated that many different facets existed within the literature to support curricular evaluation but contained little agreement on baselines or what constituted innovation within a program.

The next chapter looked at literature as it related to the project. Topics surrounding the subjects of computing education, diversity in computing, computational thinking, pedagogy, cybersecurity education, ethics and philosophy, and liberal arts computing were all examined. The literature expanded the research questions' understanding and enhanced the findings' understanding.

Chapter Two

Review of Literature

Introduction

The early papers about computer science as an academic discipline in the liberal arts context presented computer science and liberal arts as a dichotomy. The perceived dichotomy was because the origins of the field were found in mathematics and engineering and, thereby, not part of the traditional definition of the liberal arts. Computer science, or the broader term *computing*, was utilized as the root discipline and includes sub-disciplines such as information technology and cybersecurity. The inclusion of computer science in liberal arts institutions differed from how one traditionally thinks of and defines the liberal arts.

D'heedene (1982) introduced the seminal work depicting computer science education in the liberal arts described as comprising about two-thirds of liberal arts and sciences, while the remaining one-third was devoted to computer science courses. The initial literature dissected the assumption that computer science does not achieve learning outcomes by training students to think versus regurgitate facts. The goals and methods were not opposed but fundamentally the same. The availability of people, equipment, and related materials was a core challenge in the 1982 paper (D'heedene, 1982). Moreover, resources have been a long-standing issue within liberal arts institutions and continued into the most recent literature on computer science education in the liberal arts (Teresco et al., 2022). Therefore, an identified issue has been the availability and training of instructors from the earliest days of programs within the liberal arts context to the present.

Historical Background

There was much in the way of curricula and certification studies regarding cybersecurity. However, the topic quickly becomes muddled by competing priorities and methodologies when placed in the context of liberal arts institutions. Indeed, there was little consistent information for institutions to base their curricular designs on. Additionally, the cybersecurity discipline was relatively new in curricular guidelines for undergraduate programs, having not been issued as an independent discipline until 2017, at least under the Association of Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE) curricular guidance for undergraduate programs (Joint Task Force on Cybersecurity Education, 2017). The basis of these programs was an important distinction. What programs will look at was just as significant when developing or changing cybersecurity programs' curricula. Nevertheless, the basis was further confused when put into the unique context of liberal arts programs.

When simplified, liberal arts education aims to produce a holistically developed individual (Baldwin, 2018). Both historically and currently, liberal arts university mission statements circle variations of this theme of wholeness. The definition of *holistic* or *fully developed* in the liberal arts context has an outcome of an individual who has learned how to think versus simply learning a defined set of information. Their goals were accomplished by exploring topics involving the humanities and natural and social sciences. According to the American Association of Colleges and Universities (n.d.), liberal education is cross-disciplinary, combines academic and experiential learning, and has the outcome of developing learning critical for work, citizenship, and life.

Another definition of a liberal arts education was having the outcome of people who can "think, learn, be creative, and adapt to change" (Detweiler, 2021, p. 31). These definitions provided a more comprehensive basis for the philosophical viewpoint of educational development that prepared an individual for a successful personal and professional life. Much literature on the topic in the context of the liberal arts spent a significant time defining what the reader should use as a definition of liberal arts. As such, any reader of the literature on the liberal arts should consider the author's meaning and the indicated assumptions of the definition of the liberal arts to provide additional context and relevancy to the subject under review.

The term *liberal arts* originated from the Latin words *trivium* and *quadrivium*, comprised of the seven areas of the liberal arts. The *trivium* consists of grammar, rhetoric, and logic, while the *quadrivium* consists of geometry, arithmetic, music, and astronomy. These areas focused on thinking skills were distinguished from the practical arts, which traditionally have included computing disciplines. Thus, in this literature review, *liberal arts* were broadly interpreted to include newer disciplines or newer interpretations of the traditional seven liberal arts.

Another poorly defined nuance in the literature was the benchmark for a liberal arts institution. Various institutions identify as liberal arts schools, but they can be challenging to confirm. A broad definition includes liberal arts universities where 50% of their graduates receive degrees in the liberal arts. However, they could also be considered comprehensive universities (Morse & Brooks, 2022). This literature review used a broader definition of liberal arts, encompassing how institutions identify themselves, including the graduation of 50% or more of their students with liberal arts degrees, extending to more general applications of fields such as business and computer science. Since graduates potentially pursue various careers when completing computing programs, their various experiences support the inclusion of computers and business in the liberal arts (Walker, 2018).

When designing or reviewing a curriculum, one aspect is how to add new elements to a program. Walker (2018) identified four ways to add new material to a computing curriculum: 1) expand the number of courses, 2) expand the content within existing courses, 3) increase the efficiency of existing courses, and 4) drop other material to make room for new material. Suggested was a mix of these methods in the context of liberal arts computing programs attempting to integrate more recent concepts and the identified trend of resource constraints. Notably, in liberal arts programs, various institutions had differing goals, missions, priorities, and perspectives, leading to the diverse implementations of programs (Walker, 2018). The literature demonstrated that debate still existed about what constituted a computer science education in the liberal arts, much as it has been since D'heedene's (1982) original paper. There can be no consensus if it does not matter to have a uniform baseline (Fee et al., 2017).

The applicability of models as a foundation for curricula has existed since the seminal paper on liberal arts computing (Worland, 1978). Worland (1978) explained that courses taught by instructors trained in disciplines or areas other than computer science were a problem. D'heedene (1982) also discussed that trend. One key element from the literature was the previous concern on instructor background that had driven computing programs in the liberal arts for many years. The concern was that individuals trained in the liberal arts and those trained in the then-emerging field of computer science utilized different methodologies when working toward the objectives. However, in contrast, D'heedene (1982) defined them as fundamentally similar.

Therefore, in the past, computer science and its associated fields, such as information technology and cybersecurity, were considered irrelevant to liberal arts educational methods. This concern might explain why institutions added many computing programs to liberal arts institutions later than their counterparts, although the literature has not explicitly explained whether that was the case. Notably, Fee et al. (2017) and Walker (2018) explicitly outlined that computer science is still in its infancy, being less than 60 years old, compared to other disciplines found in liberal arts colleges.

Therefore, further discussion and analysis of how computer science and its associated programs fit into the liberal arts were required to address this latent and lingering criticism. Bogolepova and Malkova (2018) addressed another criticism that higher education in modern times should have the outcome of career preparation versus the broad-based education that is the traditional hallmark of liberal arts educational programs. Moreover, Leebaw (2018) identified that liberal arts institutions had traditionally resisted association with vocational training, viewed as contrary to the classical view of the liberal arts.

Bogolepova and Malkova (2018) expounded on this balancing act, showing it as potentially challenging with the higher tuition rates often accompanying liberal arts institutions' real or imagined potential for elitism. This perception of frivolous or unnecessary extravagance has been particularly prevalent in times of economic crisis. However, it was incorrect to assume that liberal arts programs merely impart superficial or useless knowledge. On the contrary, an element of the criticism of liberal arts programs broadly was that it does not focus on specific deficits. Instead, it claimed that the liberal arts do not adequately prepare students for the workplace.

This sentiment originated from the assumption that these program types contain superficial or useless knowledge. However, considering the literature that has shown the goals of computer science and liberal arts programs of teaching how to think about specific topic alignment, the broad basis of computing education within the liberal arts paradigm was a close fit. Leebaw (2018) covered the alignment of liberal arts philosophical approaches with practical career preparation well, conveying that a continually emphasized outcome of a liberal arts education was critical thinking. The result was that many modern liberal arts programs could be considered more of a blend of liberal arts and professional programs instead of classically defined liberal arts institutions.

Computing programs within the context of applied or experiential learning have further mitigated concerns about the dichotomy between experiential and theoretical learning approaches. According to Coffey and Davis (2019), studies have shown that employers favor candidates who can use the knowledge gained in higher education programs. Moreover, such as graduate school, experiential learning does not preclude further education. In one study, 37% of the participants had completed a master's degree (Coffey & Davis, 2019), directly contradicting the bias against programs in the liberal arts that emphasize career preparation. However, the consistent trend in the literature demonstrating and defining liberal arts and its application has indicated that the bias against being perceived as career preparatory existed to some extent.

Coffey and Davis (2019) used student-athletes as an example of preparing for life and emphasized how athletics was a valid method of pursuing these goals. This study also differed from the traditional definition of the liberal arts by including sporting programs as an element of comprehensive education. It would be challenging to find a post-secondary institution, whether it identifies itself as liberal arts, without an athletics program. Thus, the movement against including career preparatory programs, sometimes considered the business and computing-related fields, demonstrated the need for a broader, more modernized definition of the liberal arts.

The specific concept of applying a theory to an application was the element of critical thinking found in the interdisciplinary nature of a liberal arts education, regardless of the specialization demonstrated by selecting a degree program. A more recent qualitative study by Tieken (2020) helped discount this impression by showing that parents viewed a liberal arts education as an opportunity to view many possible career paths and garnered more attention than an alternative educational path.

Moreover, the study by Tieken (2020) demonstrated a divide between rural and urban environments regarding parental involvement and the chances of pursuing higher education, showing that rural prospective students could potentially be disadvantaged due to lower education rates, resulting in less support and encouragement to seek post-secondary education. The study highlighted that this challenge could be particularly present when a private, selective, liberal arts institution was involved (Tieken, 2020). The study concluded that outreach was the biggest challenge in assisting prospective students with whether to engage in further educational initiatives. However, the pool of participants was a limiting factor since the study surveyed students who had already committed to college. Thus, there was some inherent bias in the results, so Tieken (2020) stated that future studies should include undecided students to capture an understanding of this segment better.

Stross (2018) emphasized the practicality of education and the abilities, skills, and dispositions assisting with a successful introduction into the workplace. When reviewing, Morin (2019) noted a limitation of Stross (2018) that the experiences depicted by students were from one university, so a follow-up study should include a more comprehensive selection of students from other universities and colleges. Another potential resistance point was utilizing the term *liberal* and its modern context and misunderstanding in a particular context. The presented resolution defined and explained the basis and definition of liberal arts.

The ideal liberal arts student not only learns how to think but becomes a firm believer in identifying the why behind a problem or question (Morin, 2019; Stross, 2018). While often seen as not imparting skills, learning how to learn was extremely practical within the workplace. Placed within the context of computing programs and the modern permeation of technology on various societal facets, the ideal liberal arts student becomes essential in further using technology. The pace of technological progress was so swift that it required the ability to learn a multitude of computing aspects versus a particular one.

The study stressed that the benefits of a liberal arts education are just as great outside of career preparation. Indeed, the literature continually stressed that liberal arts students are more flexible in thinking and achieving success in their chosen vocation. Further support for the liberal arts context in computing was apparent in the latest ABET (Accreditation Board for Engineering and Technology) standards and a literature review focused on meeting more altruistic goals of public health, safety, and welfare, which requires a breadth of academic areas to be covered (ABET, 2018; Natarajarathinam et al., 2021; Raj et al., 2022). However, few liberal arts computing programs are ABET-accredited (Teresco et al., 2022). The current literature does not fully answer whether fundamental philosophical differences existed between achieving ABET accreditation and the goals inherent in liberal arts computing programs. The curricular requirements for ABET accreditation may be contrary to the number of credits required for general education typically found in a liberal arts-based educational program (Blumenthal, 2022b).

While vague in its application, the inclusion of altruistic goals within the ABET standards demonstrated a need for a broader topic base in undergraduate programs. Additional literature has supported the concept of civic duty as an essential element in cybersecurity education (Dawson & Thomson, 2018). Due to employees' increased access, the sensitivity of data professionals can access, and the increased awareness of duty and ethics are critical elements of undergraduate education.

Dawson and Thomson's (2018) study found the commitment to the values of an organization and nation to be a potential mitigating factor in future risk, albeit a more challenging one to quantify within the research context. The authors further criticized developing a baseline in cybersecurity skills since many programs strongly emphasize technical skills. The resulting focus on that facet reduced or eliminated other factors, such as understanding how user behavior influences security operations (Dawson & Thomson, 2018).

Criticism and concerns about liberal arts focus in computing education were reasonably answered with the associated literature, but the challenge of facilitating the implementation remained. According to Roberts et al. (2018), the faculty in computing-related programs are often too engaged in daily responsibilities to build cross-disciplinary approaches or address significant institutional concerns. Roberts et al. enhanced and expanded earlier literature that identified instructors as a limited resource, often overextended or required to teach courses outside their specializations. Moreover, Roberts et al. believed this issue led to institutions being likely behind in educational best practices. The requirements of time, availability, and drive are core to integrating best practices, and as such, the point was secondary but influenced other areas of challenge.

An additional challenge with cross-disciplinary initiatives was with individual faculty. Walker (2018) highlighted this challenge. He explained that while new opportunities and collaborations would be ideal in the long term, in the short term, such efforts do not fit within the typical reward systems at many colleges and universities.

Roberts et al. (2018) elaborated on this idea, stating that faculty and administration view efforts for building programs differently and, therefore, tend to avoid engaging in programs that facilitate cross-disciplinary programs. Their recommendations were developing a shared vision and considering STEM-related programs as a single division. As these programs often compete for limited institutional resources, the likelihood was that they might not be easy to implement despite the literature providing a solid case study for methodology and the positive benefits demonstrated. The previous literature had shown the overextended nature of faculty as a challenge, which would be a further deterrent to introducing new or novel cross-disciplinary programs. While a shared vision would remove some resistance to change, recognizing the need for change was not an identified issue. However, the coordination and availability of the different constituencies were (Roberts et al., 2018).

While K-12 educational standards were not a focus of this literature review, they had implications for academic requirements in institutions with teacher education programs as they progress. For example, North Dakota has moved to establish teacher credentials in computer and cybersecurity (Foresman, 2019). Unpublished drafts of future requirements indicated the trend of including computer science and cybersecurity as mandatory educational requirements at the K-12 level.

This research project's narrower context was cybersecurity in liberal arts institutional programs, which has traditionally been part of computer science and information technology programs but had not previously been an independent academic discipline defined by the ACM/IEEE guidance documents. While there was not a size of institution or program implied, these programs are typically smaller, even when part of a more comprehensive post-secondary institution. Indeed, research into the niche comprising liberal arts cybersecurity programs and their implementation had been almost non-existent. Also lacking was an understanding of the level of integration of cybersecurity curricula or concepts into general education requirements. While general education requirements for post-secondary degrees were not the primary focus, computing programs typically facilitated these requirements involving their subject areas.

The Cyberpaths study evaluated a first-year experience (FYE) concept combined with experiential learning within a liberal arts context (Mountrouidou et al., 2018). The FYE was one approach to the initial year of undergraduate education that merits mention. The Cyberpaths program was unique because it was one of many different FYE courses available, Cyberpaths being the cybersecurity-related offering. Another key differentiator was that the program focused on the newest post-secondary students as a part of general education requirements. Therefore, primary cybersecurity education served as a basis for understanding for all students participating in this particular FYE.

It was unclear how many institutions had made cybersecurity part of their general education requirements since no literature has addressed this topic. The gap in the literature was that general education typically comprises most liberal arts students' coursework. As such, the question remained whether all students are learning cybersecurity concepts as part of their education or only those studying computing-related majors. However, there was a literature gap between general education requirements and specific curricular content such as computer science or cybersecurity, further emphasized when combined with the context of a liberal arts philosophy.

An undergraduate student's general education requirements are a significant portion of their overall program, so the makeup of these requirements was significant not only for computing students but also for students in any discipline. D'heedene (1982) defined the breakdown as two-thirds liberal arts and one-third computer science. D'heedene further established that intent of most of the coursework in a liberal arts program was not discipline-specific.

The Cyberpaths program was not fully adopted into the general education requirements as it was an optional program. However, Mountrouidou et al. (2018) demonstrated that it filled the general education requirements for students engaged in the pilot program. Furthermore, participating students could be from any major, and no restrictions existed forcing students taking the class to only be from computing-related degree programs. Indeed, the program's stated goals were to introduce cybersecurity concepts to non-majors, facilitate hands-on applications, and encourage all students to contribute to the field of cybersecurity, even if the field was not their primary focus.

The study met its objective since not all participants were computing majors. Of the students who participated in the survey, 87% agreed or strongly agreed about the critical nature of the topic as a course of study (Mountrouidou et al., 2018), certainly supporting the objective of having a holistically developed individual espoused by the literature on liberal arts and more recent computing programs. The Cyberpaths project expanded the cybersecurity paradigm as an element of a holistically developed individual by emphasizing experiential coursework to facilitate broad career preparation and provide possible implementation methods.

Moving forward, the remaining sections of this literature review comprised of deeper dives into the specific areas of the literature-gathering process, the theoretical framework of the project, pedagogy, general computing education, computational thinking, cybersecurity education, ethics and philosophy, and the intersection of these topics within the context of liberal arts institutions and computing programs.

Literature Gathering Process

The literature reviewed contained references to journals and articles. The material was sourced from multiple locations but primarily searched via the University of the Cumberlands library, ACM Digital Library, and IEEE Xplore. In order to replicate this research, the project utilized the following keywords and combinations to conduct searches: liberal arts, education, quantitative, qualitative, cybersecurity, information security, curricula, curriculum, guidance, integration, and pedagogy.

Most of the literature utilized, excluding seminal works, was from within the last three years. The 2017 release of the ACM/IEEE curricular guidance on cybersecurity was the first guidance as an independent discipline for cybersecurity from that organization (Joint Task Force on Cybersecurity Education, 2017). From 2017 onward, there was a sharp and identifiable spike in the literature on cybersecurity in an academic curricular context.

The literature covered the areas of educational theory, computer science education, cybersecurity, cybersecurity education, philosophies of technology and innovation, and relevant applications of these areas in the context of liberal arts undergraduate institutions. The literature on the grounding framework of phenomenology was essential to support and bridge the introductory and methodology chapters with the literature review. As Peoples (2021) stated, the framework is always phenomenology with phenomenological studies, termed in this dissertation the *grounding framework.* This hermeneutic phenomenology supported the application of different framework theories with the term *lens*. Postphenomenology cannot facilitate this in the same fashion, taking the theory past practical and valid applications for this project. Thus, the literature reviewed utilized the terminology in this context and gave additional consideration and review to contrasting or related lenses, addressing these areas with some overlap but with the specificity of the subject area.

Lens Relevant to Question

For this project on adopting cybersecurity curriculum into liberal arts computing programs, the Diffusion of Innovation Theory (DOI) was selected as the theoretical framework to utilize as a lens to view research. Rogers (1962) introduced the DOI in a seminal paper. The DOI was well established and considered a foundational social science framework. The theory was relevant to the topic as it helped explain how and why innovations grow within areas. Prescott (1995) introduced another seminal work that expanded the theory in information technology researchers' specific application, further enhancing its applicability to this context. While the subject of the curriculum studied was technical, the how and why of implementation was more related to social science theory. As such, the DOI was the most relevant and applicable lens to build on the groundwork that the philosophical framework of hermeneutic phenomenology provided.

In this project, the direct linkage was the integration of new and emerging technologies into curricula within institutions. While cybersecurity was not new in the strictest sense, the guidance on cybersecurity as an independent academic discipline originated from ACM/IEEE, released in 2017 (Joint Task Force on Cybersecurity Education, 2017). A curriculum based on this guidance would have been relatively recent in its development. A gap existed between what institutions previously did and have done since developing curricula and courses, with a definitive lack of clarity and uniformity between computer science, information technology, cybersecurity, computer engineering, and other curricular guidance documents regarding their interrelationships. The intent of the joint report entitled *Computing Curricula: CS2020, Paradigms for Global Computing Education* was to create a bridge (CC2020 Task Force, 2020). However, no subsequent literature has demonstrated or discussed whether institutions had found it applicable.

The degree of innovation and institutions' incorporation of these guidelines were the core of this research project. Rogers' (1962) DOI divided the population into five groups based on their adoption of an innovation: 1) innovators, 2) early adopters, 3) early majorities, 4) late majorities, and 5) laggards. Their distribution follows a standard bell curve. The DOI theory provided the groundwork to support the adoption of cybersecurity in programs that fall within the curve.

The exact placement of a particular institution compared to other liberal arts institutions was a potential and relevant application of the DOI in the context of this project. Recent literature by Jwaifell and Gasaymeh (2020) showed that the DOI could impact how lecturers utilize new material in classes. For example, the DOI used in the project showed that adopting innovation would result in increased future adoption.

When reviewing other theories of interest, the technology acceptance model (TAM) was another standard theory that emerged. While it did not fit this project, it led to a paper integrating the TAM with the innovation diffusion theory, which proved quite exciting and applicable (Al-Rahmi et al., 2019). Al-Rahmi et al. (2019) demonstrated the continued use and application of the innovation diffusion theory, even with newer theories developed since the conception of the DOI.

The TAM strived to explain the rate at which a specific technology element was accepted and used within a population. Both theories focused on how something was accepted, but the DOI focuses on a broader definition of innovation, not strictly tied to technology. The broader definition allowed for a project combining liberal arts, computing, and pedological concepts with sufficient latitude and flexibility while guided by a framework. This justification was that cybersecurity was accepted in an academic context but not necessarily adopted by institutions.

Jwaifell and Gasaymeh (2020) utilized this lens to demonstrate how adopting technology among a population and how peer-to-peer relationships influence the growth of technological developments within a classroom setting. Tristani et al. (2020) provided further context on the application of the DOI in the classroom by promoting and communicating available resources while emphasizing curated content. This project, which utilized the DOI, stressed that a challenge with implementing new methodologies and techniques often originated with teachers' insufficient training or a general lack of resources (Tristani et al., 2020). While the specific innovation differed from the project, the perceived complexity involved in implementing new ideas was of note and relevance.

Huang et al. (2020) offered additional relevance to new methodologies and techniques by studying the DOI in adopting open-source learning platforms. The quantitative study explored various factors and implications on technology adoption in an educational setting, supported by the DOI and its associated theories, such as the TAM. Due to the rapidly expanding impact of learning technology, the authors concluded that the investigation was crucial to the success of the associated fields of study.

Contrasting or Supporting Theories

While the lens of this project involved the DOI theory, it in no way discounted other approaches just as applicable to concepts found in computing curricula. For example, when the base factors of the DOI were considered, such as intention and exploring the similarities of the TAM, which was in turn based on the DOI, the results of studies based on the TAM become applicable even in a context based on the DOI and have been tied to improvements in student learning (Al-Rahmi et al., 2019; see also Davis, 1986). Additional research traced the history of the TAM, elaborated on its findings, and attempted to drive the theory forward with predictive explanations of how it could apply to various fields (Lee et al., 2003; Venkatesh & Davis, 2000; Venkatesh et al., 2003). The significance was that the wide variety of variables used to apply the TAM to technological aspects originated with Rogers' (1962) DOI theory.

Persada et al. (2019) built on earlier work by covering generational studies, and social psychology also built on the foundational theories of the DOI and the TAM. The unified theory of acceptance and use of technology (UTAUT) was built on these theories, emphasizing behavior intention. The UTAUT intended to explain user intentions with technology and the resultant usage. With the generational study directly relevant to undergraduate curricula, a recent study emphasized this perspective as the key to developing more accessible learning resources (Persada et al., 2019). It was considered related to the DOI, which provides a more robust and broader basis for an overall lens for this phenomenological project.

Further studies by Chipidza et al. (2019) and Moore and Burrus (2019) alluded to the DOI and the TAM by emphasizing the theory of planned behavior (TPB) in selecting career majors. The TPB aims to link beliefs to behavior. While grounded in social psychology theory, the relevance to the DOI in a project on undergraduate curricula justification was evident. There have been studies on the TPB and the selection of the management of information systems as a college major, including attempts to predict STEM majors utilizing the TPB.

The TAM, UTAUT, and TPB were highly relevant to a project on curricular selection in computing programs. However, when integrating newer technology such as cybersecurity constitutes an innovation, the earlier theory put forth by Rogers (1962) and enhanced by Prescott (1995) as more relevant to information technology researchers became the most apparent foundation as a lens for research in this project. Moreover, the TAM was considered a supporting lens for this project but not a primary lens.

Current Literature

Literature on General Computing Education Developments

Concerning the foundational literature in the field of computing education, the curricular guidance produced as a joint effort between the ACM and the IEEE-CS has also been endorsed, reviewed, and contributed to by a significant number of groups and professional organizations worldwide (Joint Task Force on Computing Curricula, 2001, 2005, 2013). In addition, the 2020 report consolidated many undergraduate computing curricula recommendations to link the sub-disciplines that had been recognized more cohesively (CC2020 Task Force, 2020).

The current computer science undergraduate curriculum guidelines originated in the 2013 release, a significant update to the 2001 curriculum guidelines from 2008, which laid the groundwork for the 2013 release (Joint Task Force on Computing Curricula, 2001, 2005, 2008, 2013). However, several updates, revisions, and newly recognized fields, such as information technology, were included in the 2008 and 2017 revisions (Joint Task Force on Computing Curricula, 2008; Task Group on Information Technology Curricula, 2017). Then, in 2017, cybersecurity finally received its guidance as an independent discipline and received further clarification and updates in the 2020 Joint Task Force report (CC2020 Task Force, 2020; Joint Task Force on Cybersecurity Education, 2017).

Most of the 2020 report was straightforward in the material covered and added. Technology has grown and changed, and the need to approach it differently in an educational setting. However, one key differentiating factor from previous revisions to curricular guidance was a transition from knowledge-based to competency-based learning (CC2020 Task Force, 2020). The 2020 report defined competency as knowledge plus skills and dispositions or knowing the why of the matter (CC2020 Task Force, 2020). Clear et al. (2020a) made new efforts to lay a foundation for converting existing curricula toward a competency-based program. Impagliazzo et al. (2022) further reviewed this trend, emphasizing competencies for computing graduates. While much of the expanded content was unavailable as a writeup of a panel session, the information contained within the writeup elaborated and better-defined professional dispositions. One example was that professional dispositions, seen as a requirement in a computing program, were defined as cultivated behaviors desirable in the workplace (Impagliazzo et al., 2022). Therefore, computing undergraduate educational guidelines became essential in tying student outcomes to curricular planning.

This change in basis was a shift in the foundation of computing education curricula outcomes from memorizing elements of the body of knowledge to applying and utilizing that knowledge in a larger societal context. As this foundation related directly to the principles emphasized in a liberal arts education, the overall computing guidance shifting toward emphasizing practical application was unexpected. The report also recognized how computing permeated many aspects of society and clarified how the computing fields related to broader topics (CC2020 Task Force, 2020).

Further work presented by Clear et al. (2020b) provided additional pathways and methodologies for programs to begin transitioning to the competency-based curriculum guidance found in CC2020. The curricula guidance continued to develop, and the ACM/IEEE was already working on updating the computer science curricula guidelines for undergraduate programs (Kumar & Raj, 2022). Published drafts of CS2023 showed the proposed revisions in the CS2013 release, which engaged the community to solicit feedback on the revisions (Kumar & Raj, 2022). Blumenthal (2022a) offered that an essential criticism of the CS2013 guidelines was specific flaws, leading to a need to include complexity and computability theory. However, the author also acknowledged the trend for programs to attempt to reduce the overall number of credit hours.

The CC2020 Task Force report also included and expanded on Computing + X (CS+X) or X + Computing (X+CS), where the X indicates another discipline, and the order merely tells whether the basis was computing or a different domain. The concept of combing computer science with other fields was certainly not new. Areas recognized now within computing are computer engineering, computer science, cybersecurity, information systems, information technology, and software engineering grew out of domain combinations

. Moreover, data science has evolved from new technologies developing its own distinct needs, maturing into an independent field (CC2020 Task Force, 2020). At the same time, these fields could be considered outgrowths of computer science in their separate disciplines. The initial development of those fields developed by bringing in other areas, such as business, for expansion. With computing becoming pervasive as a significant need for a technologically aware workforce, combining computer science concepts with other disciplines has become more common, necessitating the inclusion of a mention within the curricular guidance (CC2020 Task

Force, 2020). Any program development should, at a minimum, have evaluated the inclusion of computing topics within other disciplines or how their courses facilitate computing students' understanding of different disciplines.

Interestingly, the CC2020 Task Force (2020) compared the differences between the disciplines using three groups: hardware, software, and organizational needs, with hardware and software overlapping some computing areas. However, the CC2020 Task Force also compared various curricular guideline documents, showing how they overlapped more significantly, which might have impacted the utilization and acceptance of the various guidelines. Thus, it was convoluted and unclear which guidance to use.

A possible gap in the report was how to consider the disciplines in a more hierarchical fashion, which might establish an order of precedence for programs when evaluating curriculum. For example, it could determine when a program should use computer science versus cybersecurity curricular guidelines to include security courses as part of the curricular content within an institution's program.

The report also addressed, or at least acknowledged, fields that had emerged, such as blockchain and the Internet of Things (IoT), although it did not address where they fit into areas beyond accepting that they exist and might have been short-term trends (CC2020 Task Force, 2020). Burd et al. (2018) utilized the IoT as another example of methodologies and pedagogical approaches to implementing a new curriculum. An Innovation and Technology in Computer Science Education (ITiCSE) working group for foundational material occurred in 2017 and 2018. The final paper did not present solutions, yet the authors identified a need for more comprehensive pedagogical approaches in the IoT discipline relevant to other emerging fields (Burd et al., 2018).

A lack of emphasis on integrating the command line interface (CLI) into computing curricula also emerged in the literature. For example, Berry and Rousseau (2022) presented a new tool called ShellOnYou to assist with integrating CLI experiences in computing programs. The reasoning provided by the authors was that Unix-type systems are predominant in many computing facilities, and students from other disciplines, such as physics and social sciences, are also likely to benefit from learning CLI techniques and experiences (Berry & Rousseau, 2022).

Garcia (2018) explained that computing education focuses on how to teach identified concepts effectively. The flipped classroom pedagogy has been widespread, emphasizing engagement with the material before a class session. Guided practice worksheets as course enhancement tools had proven positive in terms of completion rate and overall course grade. Providing a framework and guidance supports instructors in implementing new techniques and methods, which was critical in the shifting educational landscape.

This shift was demonstrated previously with the ACM 2020 report codifying these changes (CC2020 Task Force, 2020). In addition, a recent paper identified pedagogy as a particular gap in university computer science programs. Friend et al. (2021) ascertained that although many universities felt well-positioned in content knowledge, their methods courses explored different approaches. The most significant gap between the panel discussion and the paper was that it focused on educational programs for computer science teachers, thereby leaving out the concept of general pedagogical approaches of university computer science faculty.

Curriculum designers developed learning objectives for programs and individual courses from guidance and developments in approaches. Mitchell and Manzo (2018) conducted recent research that indicated that many faculty from large R1 state universities or smaller liberal arts colleges found them confining and did not overly impact student learning. The problem was that the study did not fully represent the audience of accreditation and assessment individuals. Learning objectives provided a baseline for this group, so additional research on bridging the two audiences would be highly relevant to the curriculum and program development.

Virtual learning certainly existed for a long time in computing educational developments. However, the COVID-19 pandemic further accelerated its application. Iivari et al. (2020) stated that academic courses in a post-secondary environment must account for individuals coming into the traditional university setting with a much higher comfort level and expectations about virtual courses and course delivery options. A critical distinction in a study on the pandemic and digital transformation was that, while pervasive, not all younger individuals benefited from the sudden digital change (Iivari et al., 2020).

During the digital transformation enforced by the COVID-19 pandemic, a specific area performed traditionally hands-on activities and laboratory work. Estriegana et al. (2019) conducted a study to gauge student acceptance of virtual methodologies with positive discoveries. A positive enhancement was moving work to an online medium with approaches such as gamification. Higher satisfaction resulted in higher completion rates, which were also influenced by how easy the system was to use (Estriegana et al., 2019). Ease of use was a critical factor particularly evident in 2020, with significant impacts on many cloud services and a sudden shift to fully online environments globally across all levels of educational activity. The literature in other fields, such as cybersecurity, demonstrated positive results in the mixed delivery approaches (Hassan, 2020).

Attempted were various approaches to online-centric modalities resulting from the blurring of boundaries due to the massive shift from the traditional classroom to online-centric modalities. The literature had begun to discuss what worked and might be applicable. In one instance, a forced higher engagement rate than typical in an online course resulted from using a Discord bot (Wright et al., 2022). The approach was novel and addressed many issues found in existing attendance-taking methods. Moreover, Ritz and Grüneke (2022) investigated the concept of learner analytics and student dashboards in their research. A limitation of the study was that it contained a limited group of stakeholders in educational platforms. Finally, Şahin et al. (2022) continued the trend of remote learning in the literature with different perspectives of the emotional outcomes of students during forced online educational modalities. The future transferability of the study resided within the unknown of additional pandemic concerns, yet addressing what worked in that context would be necessary for future studies (Şahin et al., 2022).

Literature on Diversity in Computing

Academically and professionally, diversity in computing has been a strong constant within the reviewed computing literature. One of the most recent pieces of literature on diversity in computing by Vrieler and Salminen-Karlsson (2022) presented a framework that educators can utilize to make computer science education more inclusive, specifically, computer science capital (CSC). The CSC framework facilitates computing educators in reflecting on their practices, making computer science education a more diverse and inclusive learning environment for students.

In their paper, Vrieler and Salminen-Karlsson (2022) argued that sociology could inform their work. The paper examined three theoretical lenses: Bourdieu’s (1986) notion of capital, Archer et al.’s (2015) view of science capital, and the sociocultural theory on learning to develop CSC. The relevance of this literature was that it discussed diversity and inclusivity at younger student ages. However, Vrieler and Salminen-Karlsson (2022) also enabled educators in undergraduate computing programs to identify and address how they might account for diversity and inclusivity in their pedagogical approaches.

Bourdieu's (1986) notion of capital conveyed that access to resources may help or hinder an individual's social mobility. Vrieler and Salminen-Karlsson (2022) reviewed social capital in the context of Bourdieu as an individual's ability to access other people's social resources. The significance in the context of computing education was that each person has a different composition of capital. Therefore, making assumptions about an individual's aspirations in learning computing disciplines should not be done. Vrieler and Salminen-Karlsson (2022) mentioned a tangent, but a critical observation was that many instructors are recruited to their roles for discipline-specific knowledge and typically have little formal training in pedagogy, diversity-aware pedagogy training, or learning strategies.

Nevertheless, they were responsible for transmitting the dominant culture of the computing discipline. An essential point from the authors was that the dominant views tend to unconsciously perpetuate the White male privileged student as the most interested in computing. As a result, the discounting of the viewpoint made the discipline less appealing to students of different backgrounds.

Vrieler and Salminen-Karlsson (2022) showed that the second lens of Archer et al. (2015) on science capital built on Bourdieu's (1986) notion of capital connected to the context of computer science. Then, the third lens of the sociocultural perspective demonstrated that learning and knowledge depend on the socio-cultural context from which a person originates (Vrieler & Salminen-Karlsson, 2022). With its foundational lenses, the concept of CS comprised "CS social capital, CS cultural capital, and CS behaviors and practices" (Vrieler & Salminen-Karlsson, 2022, p. 7). While the full review and analysis of these components were outside the scope of this literature review, awareness was necessary for this recent development in computing education.

Other examples provided by the authors included popular culture and technology icons, such as Bill Gates and Steve Jobs, who perpetuated environments that did not foster an inclusive nor diverse learning environment (Vrieler & Salminen-Karlsson, 2022, p. 17). Computing educators could use this concrete example to provide a critical reflection and offer better chances for students of diverse backgrounds to feel included. The authors concluded that CSC was a reflective approach for computing educators to reflect on their teaching and make more significant strides in inclusive learning environments (Vrieler & Salminen-Karlsson, 2022).

Gender inequality was a primary trend addressed in diversity issues relating to computing, as it remains a significant problem in the information technology sector (Grabarczyk et al., 2022). A key recommendation from Grabarczyk et al. (2022) was that universities should add material that better balances computing to everyday life and societal matters in comparing people versus things. One similar option for increasing diversity awareness in computing education was presented by Leutenegger et al. (2022), using an interactive theater group to present scenarios displaying gender bias and engaging the students in how to recognize and address it. What differentiated the approach was that it was delivered over five years, so it provided examples and student feedback on how the approach was perceived. While a small percentage of students did not believe the approach was helpful, the student survey respondents generally indicated an increased awareness of gender biases, with valuable tools to help address them (Leutenegger et al., 2022).

Brodley et al. (2022) recently demonstrated that combining computer science-related courses with other disciplines could increase diversity and student interest, also connected to the

CS + X topic. For example, Khoury College at Northeastern University created its first combined major in 2001 and saw a dramatic increase in the number of combined degrees and participating students. Of note was that an increase of diversity and representation of computing graduates markedly increased, particularly among female graduates, compared to traditional computer science programs (Brodley et al., 2022). This demonstration of emphasizing the program structure's inclusivity and impact on diversity was highly significant.

Literature on Computational Thinking

The literature has captured the necessity of including computational thinking as a critical element of a modern workforce. The topic's prominence in the last few years originated with a seminal article on computational thinking, expanding the discussion from a computer science basis to emphasizing integration into other disciplines (Wing, 2006), briefly defined as problem-solving approaches to developing generalized solutions to open-ended problems. The simplest definition presented in the literature defines computational thinking as "something that people do, not computers" (Vallance & Towndrow, 2018, p. 302). While overly simplistic in some respects, it supported the overall trend in the literature that computational thinking should be part of broader educational initiatives, supported by computer science principles but not equated with them. Moreover, Vallance and Towndrow (2018) discussed coding initiatives in a positive context and made the critical distinction that computational thinking was relevant to all disciplines in the arts and humanities.

Computer science can vary in K-12 schools in terms of the content taught. Jacob and Warschauer (2018) asserted that the subject was not widely taught in these grades, though many initiatives nationally and globally exist to change it. There has been growth and demand for general STEM education, but it was purposefully broad, and computer science was only a tiny portion. Therefore, Jacob and Warschauer (2018) proposed that the solution was to partially re-frame and define computational literacy as a new form of literacy.

This proposal fits nicely into a gap left by the existing research on integrating computer programming into K-12 programs and how it benefited higher education programs. Their work was a proposal for a three-part framework: 1) Computational Thinking as Literacy, 2) Literacy through Computational Thinking, and 3) Computational Thinking through Literacy. The individual elements had nuances that, if achieved, could provide future undergraduate students with a deeper base of technological understanding when pursuing a degree.

According to Park and Green (2020), computational thinking as a practice has been gaining traction for further integration into general STEAM courses and methodologies. However, while it might be natural to assume the placement of computational thinking within this broad field, there was no discernible pattern of how organizations have implemented computational thinking within their programs. Thus, Park and Green (2020) developed a model to analyze computational thinking to capture the utilization better and ensure it within programs. Denning and Tedre (2019) phrased it as the essence of breaking down significant problems into smaller pieces and understanding what computational thinking was about and why it was a critical element of modern education.

Conde et al. (2021) provided a deeper dive into applying computational thinking in STEAM activities and reviewed the topic's literature. The study concluded that many applications existed for using and including robotics and physical devices to enhance student learning of computational thinking. Furthermore, due to popularity and comfort, students achieved better results using the tools that engaged them (Conde et al., 2021). Li et al. (2020) further developed the broader integration into STEM topics. Their definition of computational thinking focused on searching for ways to process information, stressing the importance of not limiting computational thinking to computer scientists and programming (Li et al., 2020).

Pollock et al. (2019) conducted similar work from an educational development perspective to generate a model to enhance computational thinking across various disciplines. The most significant conclusion of the study developing the model was that students received exposure to computational thinking and saw what was possible. A significant issue in the literature has been defining computational thinking. Multiple definitions over the years have been as varied as opinions about applying computational thinking in any context. Since Wing's seminal article in 2006, several opinions and approaches to the topic have grown in utilizing the STEAM fields. For example, Nicolajsen et al. (2021) presented a paper on a framework that divided computational thinking into cognitive, situated, and critical contexts. While engaging, it focused on computer science and only mentioned the need for cross-disciplinary initiatives (Nicolajsen et al., 2021).

However, one critical distinction emerged in the latest literature: computational thinking does not and should not automatically equate with programming (Tedre & Denning, 2016). Tedre and Denning's (2016) definition of computational thinking was the thought process of defining problems in which the computational steps represented solutions. This thought led to the conclusion that computing provided an interpretive lens of the world but was not the only lens. Thus, computational thinking enhances science, not replacing science with computers uniformly (Tedre & Denning, 2016). Furthermore, de Jong and Jeuring (2020) recently conducted a literature study that supported the broader approach by assessing historical interventions in various disciplines in higher educational settings. However, they concluded that the lack of standardization regarding definitions and approaches limited the effectiveness of creating and testing the various approaches to computational thinking.

Globally, governmental standards have developed in mandating overall computer science. Research on training the trainers to teach computational thinking at an earlier age was a part of such initiatives (Lamprou & Repenning, 2018). Emphasis was again placed on computational thinking being process-focused, not just emphasizing programming aspects. A notable conclusion of the study was that preconceived notions of computing are often challenging to overcome (Lamprou & Repenning, 2018).

Additionally, other literature attempted to narrow the focus to specific segments of computational thinking when evaluating the effectiveness of pedagogical methods. For instance, Calderon et al. (2019) conducted a study in the UK that specifically focused on sequential and abstract thinking processes, finding a positive correlation when effectively applying computational thinking concepts in pedagogy. The study focused on the two elements and accepted that computational thinking also includes decomposition and data representation and the connection between the focus on sequentiality and abstraction to cognitive effects in the most straightforward fashion. Nevertheless, not sufficiently addressed in the study was the limitation that the selected participants were only from undergraduate computer science and software engineering courses. At the same time, they demonstrated a positive correlation between teaching abstraction and students' ability to learn it. The study was unclear if the participant pool was predisposed to do so. Therefore, the study's validity and transferability were subject to question, though discounting the study was inappropriate.

Finally, a limited number of articles best described as counterarguments existed. Nardelli (2019) tried to precisely characterize computational thinking while emphasizing that too much of it might be dangerous to the usefulness presented in the earlier literature. Instead, Nardelli stressed a more general definition of computational thinking that approaches it as a scientific subject and has a discipline of transversal value to contribute to other disciplines. Moreover, Guzdial et al. (2019) provided another viewpoint that also questioned the trend of emphasizing computational thinking by pointing out that it emphasizes the learner. Their article proposed putting the onus back on computer scientists to design better tools since children already use computational tools, methods, and thinking. The nature of the tools and applications should have enhanced computational thinking, not force children to learn in such a fashion. While the article appeared to counter most of the literature on the topic, its essence was that computer scientists are better off reducing the significance of computational thinking as a required element of modern educational approaches.

Literature on Pedagogy Developments in Computing

When reviewing the developments in computing and curriculum, it was relevant to look at the pedagogy products concerning these fields. A significant amount of the recent literature related to the COVID-19 pandemic and academic programs that moved into an online or hybrid format. For instance, Bahamón et al. (2020) found no significant differences between different teaching modalities presented at the 2020 ACM's Special Interest Group on Computer Science Education Technical Symposium in March 2020. Notably, COVID-19 closures caused the conference to be canceled in terms of in-person attendance the morning the conference was to start, resulting in a mass shift to online learning for many universities. Therefore, the applicability and transferability of the study were questionable.

A limitation of the study was that it did not adequately address the potential issue of self-selection. Moreover, the students who would do poorly in an online course did not sign up, skewing the data (Bahamón et al., 2020). A follow-up considering the shift after Spring 2020 could resolve this limitation. Additionally, the design and intent of an online course modality was an element that did not appear to be considered by the authors. Therefore, the COVID-19 pandemic possibly influenced and potentially invalidated the study, as presented in the paper.

Singh et al. (2021) provided one of the most valuable papers on the issue, which examined the history, evolution, and methods in the medium of instruction and presented solutions and recommendations for implementing them, building out the infrastructure to support a traditional or hybrid learning format. It also encouraged the faculty to become more familiar with online tools. The proposed point would be that of preparation if they were unfamiliar with them in the event of another emergency.

With the COVID-19 pandemic, the literature and recommendations quickly became muddled, and often there was no differentiation between K-12 and post-secondary education needs. Shamir-Inbal and Blau (2021) conducted a quantitative study investigating the results of emergency distance learning and discovered that pedagogically, teachers acquired new teaching and technology skills that they might not have otherwise. Jorge-Vázquez et al. (2021) confirmed that universities with better technological resources and training available to faculty resulted in a higher level of digital skills. While the expected resources were more likely to exist in more prominent universities, training plans were crucial for successfully converting teaching modalities.

Other popular pedagogical trends in the literature were flipping and learning progressions. For example, Bredow et al. (2021) conducted a study that examined flipped classrooms in higher education. It noted that many previous studies had focused exclusively on academic achievement but did not adequately cover interpersonal or satisfaction-related metrics on flipped classrooms versus lecture-based course delivery. The study discovered that positive gains could be demonstrated 88% of the time across all three metrics. However, it also concluded that not all flipped outcomes were significantly beneficial. For example, while engineering and mathematics classes could see the benefits of flipped classes instead of lecture-based classes, the difference may not be as significant as in other educational contexts.

The literature on professional development for teachers better explained facilitating STEM education topics. For instance, Jong et al. (2021) provided a central paper that reviewed the literature and collected it to provide a comprehensive set of ideas to facilitate designing and implementing teacher professional development for STEM educators. While much of the literature discussed concepts of self-learning, Jong et al. (2021) highlighted the critical role educators play in supporting learning. As such, development was essential for these teachers. It expanded the context of the material and looked at studies relating to teacher professional development and STEM education.

The paper had two key findings. First, STEM knowledge of a particular might be limited and hindered by a lack of preparation time and resources (Jong et al., 2021). While a limitation of the study was that it was limited to PreK-12 education, it was applicable in the context of STEM teacher education. It was similar to the constraints expressed in liberal arts computing programs. In the context of STEM education, parents' thoughts and opinions were also seen as an additional driver leading toward the perceived importance of computing topics and should be considered (Solyst et al., 2022).

Gamification was another trend in computing education that had been useful in teaching research methodology. Marnewick and Chetty (2021) showed that gamification could integrate and break down complex problems into a methodology, forcing students to engage with the theory while applying it in practice. Furthermore, Silva (2020) presented a new term and concept to develop the *education serious game*. Silva (2020) offered a methodology to facilitate communication between designers to better differentiate between the mechanics of the game and the educational concepts conveyed within that game.

Higher education applications also were accounted for in the literature, such as structured query language (SQL) gamification in an online setting (Tuparov & Tuparova, 2021). The quantitative study found positive student feedback, so the authors concluded that further gamification applications would be warranted. The gamification of SQL and the associated tools mentioned differed distinctly from using Parson's problems in SQL exercises.

Borchert and Walia (2022) covered the increased discussions on Parson's problems, which saw growing attention in the literature as another applicable methodology for scaffolding in computer science-related courses (Borchert & Walia, 2022). Ericson and Haynes-Magyar (2022) further explored adaptive Parson's problems as a methodology to engage the students in active learning. However, they found that the methodology was perhaps best suited to a lecture environment where providing individual help to struggling students could be more difficult (Ericson & Haynes-Magyar, 2022). There was a gap in the literature as to how the methodology might work in a smaller environment where students can acquire more individual assistance and attention.

Another methodology in the literature has been the usage of storytelling as an instructional methodology in computing courses. Burton et al. (2018) published a seminal article that applied science fiction to teach computer ethics, which stressed that the relevance and applicability of using science fiction in that context was the ability to foster safe and reasoned learning and discourse without making the discussion personal (Burton et al., 2018). The article also supplied recommendations for content with an example syllabus to facilitate the adoption of the methodology in similar or other computing contexts. The method demonstrated promise, but no other recent literature had covered this specific methodology, so it was difficult to determine whether that was a trend or merely a novel approach.

Bates et al. (2021) built on an earlier article by Burton et al. (2018) in a special SIGCSE session, though there has been no publication of the outcome. The proposal expanded and reinforced that storytelling can facilitate the discussion of complex topics while removing barriers (Bates et al., 2021). The planned future outcome was a framework to facilitate the adoption of ethical material in courses, particularly for students or faculty with limited experience in ethical frameworks.

Arnedo-Moreno and Garcia-Font (2021) studied how cybersecurity implemented fictional storytelling in an academic course context. The composition of the study was 111 participants who were surveyed on their experiences with the instructional design methodology using a digital novelette and the application of fictional narratives about computer security. The authors demonstrated that the approach's applicability was equal to classical techniques. However, they noted that the cost of creation was higher than classical approaches but lower than the development of an *education serious game* (Arnedo-Moreno & Garcia-Font, 2021).

Park (2021) delved into the literature surrounding future instructional method development and topics, including blockchain technology, in an academic context. Blockchain influences topics such as business, finance, computing disciplines, and other fields with concepts and applications, such as the distributed ledger, as a growing trend in computing education, so topics like big data are now considered mature (Park, 2021). Park noted that most of the literature focused on the potential of blockchain versus its application and usage, citing the earlier literature showing that blockchain could significantly impact learner assessment and evaluation, fostering learning about technology and cryptography, even outside traditional computing programs.

Sharp et al. (2020) identified a developing area in the pedagogical approaches to computing education within the scope of agile methodologies. The paper conducted a significant review and identified several papers published on the topic, which explored the application of the agile methodology in teaching non-agile content while using non-agile pedagogical approaches to teaching agile content (Sharp et al., 2020). While some papers dated back to 2005, there was a distinct increase in 2016, with the majority from 2018. Sharp et al.'s research demonstrated that while agile has existed since 2001, the application as a pedagogical approach was more recent but gaining attention. However, the study's limitation was that the search criteria did not include non-English sources in the review (Sharp et al., 2020).

Literature on Cybersecurity Education and Developments

The field of cybersecurity education was a natural result of the growth and maturity of computer science as an academic discipline and a profession. Cybersecurity was not a new topic. In the United States, legislation has existed since the 1980s, as demonstrated by the Computer Fraud and Abuse Act of 1986. The earliest notable criminal case was the United States vs. Morris in 1991, the case being an outcome of the Morris worm of 1988, which significantly impacted infrastructure as it existed at the time. While various professional organizations, such as the National Institute of Standards and Technology (NIST), the ACM, and the IEEE, have set educational requirements, splitting cybersecurity into a distinct academic discipline and providing curricular guidance was relatively new.

A seminal work on establishing curricular guidance was in the context of the information technology model curricula (Rowe et al., 2011). The authors felt it was a natural fit within the information technology field and stressed how cybersecurity had been a longstanding need. In addition, Rowe et al. (2011) mentioned that elements of the field resided in other disciplines, so cybersecurity could be considered multi-disciplinary.

The ACM/IEEE Joint Task Force released curricular guidance for higher education cybersecurity programs in 2017 (Joint Task Force on Cybersecurity Education, 2017). The guidance was a natural progression from the curricula guidance for computer engineering in 2004, computer science issued in 2005, and the information technology guidance published in 2008, and again in 2017 (Task Group on Information Technology Curricula, 2008, 2017). As the field has grown, matured, and developed new fields, educational needs have also evolved. The cybersecurity guidance released by the Joint Task Force on Cybersecurity Education (2017) and other contributing groups defined the field, the framework, and the knowledge covered in an undergraduate cybersecurity program. The final segment of the guidelines included the recommendations for industry standards and practices (Joint Task Force on Cybersecurity Education, 2017).

A 2020 report on paradigms in computing education also further defined cybersecurity education as a specific academic discipline with considerations and focal points (CC2020 Task Force, 2020). Notably, the phrasing changed to refer to computing as a whole and specific fields that have grown from the original computer science curriculum guidelines. Additional guidance was also issued in 2020 on associate degree programs, demonstrating the demand for expanding the guidance documents. This recognition factors into program accreditations through bodies such as the Higher Learning Commission. The recommendation was to provide cybersecurity education, even in smaller degree programs (Cyber2yr2020 Task Group, 2020).

Still, there was no indication of what post-secondary education institutions have utilized for their cybersecurity programs. Guidelines are simply that: guidelines. They are not mandatory, and the time to implement curriculum revisions and additions varies from institution to institution. Orozova et al. (2019) provided a crucial piece of literature introducing security concepts that bridged this gap by demonstrating ISO/IEC 2700 series standards. Moreover, the 2017 curriculum guidelines for post-secondary degree programs in cybersecurity have provided the newest baseline for institutions to key their institutional programs (Joint Task Force on Cybersecurity Education, 2017). The authors stressed the development of a standards-based curriculum to improve the ability to look for new approaches and apply developed problem-solving skills. Raj and Parrish (2018) proposed a similar concept in melding the 2017 curriculum guidance with ABET accreditation to begin standardizing a baseline for what constitutes cybersecurity education. Raj et al. (2022) built on that work with efforts to tie ABET to computer science competencies, including security concepts.

The literature demonstrated a desire to establish a common starting point in developing undergraduate cybersecurity degrees in a post-secondary academic environment. It did not agree that the Joint Task Force curriculum guidance of 2017 fully met the need. However, the initial 2017 cybersecurity curriculum guidance and an accreditation standard by ABET had been the most referenced. Other educational requirements were industry-driven, were from Certified Information Systems Security Professional (CISSP) certifications, or adhered to governmental standards (e.g., the NIST Cybersecurity Framework), which do not necessarily translate to an academic curriculum. Curriculum guidelines can include or incorporate various recognized or popular certifications. While a valid and helpful reference point, they are not actual curricula.

Cybersecurity as an academic discipline demonstrated additional growth and maturity through new disciplines founded on a combination of cybersecurity and other areas. For instance, Trilling (2018) proposed creating a new academic discipline called cybersecurity management education that combines cybersecurity and business management guidance concepts. However, the paper's significance in cybersecurity education and curricular development was not in the proposal itself but resided within the gap demonstrated by its compilation of the extant literature. From other curricular guides, job market analysis, and information security standards, the paper showed that with an increasingly large gap of graduating information security students to job positions, there would be an even more significant gap in individuals trained in the field also trained in management concepts and techniques.

Goupil et al. (2022) investigated the skills gap in cybersecurity. One element of the recommendations for curricular design was that they should closely look at various skill elements, such as industry certifications and security management. What was surprising from their results was that industry demand was far lower for industry certification when compared to the other elements than expected (Goupil et al., 2022).

In addition to the ABET focus, there was a slight trend in the literature to tie curriculum to DHS/NSA Centers of Academic Excellence in Cyber Defense (CAE-CD) designations (Ward, 2021). However, the limitation of this methodology research was that it was not related to the focus of two-year associate degree programs. However, the paper provided no reason or justification for why two-year or four-year programs need CAE-CD designations or ABET accreditations. There was no explicit explanation, so the implication for the reader was that it could be important for recruitment, presumed higher level of training, or similar facet.

However, Ward (2021) gave attention to the lack of hands-on application of skills found in many programs and guidelines and proposed a framework based on government and professional guidelines but failed to address why meeting the CAE-CD or the Association of Technology Management and Applied Engineering (ATMAE) standards were critical as curricular outcomes. The ATMAE was not mentioned further in this literature review as its accreditation focus was on two-year institutions, but it was relevant in this context.

The ABET accreditation status was seen as an approach to gauge the level of implementation of the CS2013 curricular guidelines from the ACM (Blumenthal, 2022b). Blumenthal (2022b) looked at the differences between ideals, requirements, and reality. The study reviewed computer science bachelor of science programs that promoted the CS2013 guidelines and to what extent ABET-accredited programs differed from non-accredited programs. Utilized to determine the primary data collection point coverage were the course catalogs.

However, this approach presented a methodological problem. There was a presumption that titles and descriptions could provide the course elements wholly and correctly. Therefore, while Blumenthal (2022b) concluded that non-ABET-accredited courses covered less of CS2013, it did not account for whether the programs contained elements within other courses or other such creative approaches in covering topics found in smaller programs.

Additionally, there was no differentiation regarding institution size within the data. However, Blumenthal (2022b) explicitly addressed a few possibilities of why non-accredited programs might have less overall coverage. The specific mention within the study of liberal arts colleges with a more extensive base of non-discipline-specific courses required for degrees might differ in their approaches and reasoning for the topics covered in their programs. Of a more controversial nature was Blumenthal (2022b) posting a question about the amount of coverage in curricular guidelines such as the ACM and the ABET as to whether these recommendations could measure a computer science program if it differed considerably from the guidelines.

OConnor (2022) presented a related paper on course design that demonstrated the balance between theory and application of offensive security methodologies to educate students better. OConnor (2022) believed that the lack of application, specifically the lack of offensive tactics in the curriculum, led to an unprepared workforce entering the field of cybersecurity. Švábenský et al. (2022) expanded this concept to facilitate student success in applied approaches. Knowledge of the command line was a specific skill identified as a need for cybersecurity students. The paper explicitly mentioned visualization as a beneficial tool for instructors to analyze student thinking better and enhance their ability to teach the required concepts. Moreover, Hall et al. (2022) further expanded with a related approach, using gamification, IoT, and narrative storytelling to teach cybersecurity concepts in an applied fashion. Thus, multiple methods and mediums have emerged as cybersecurity education trends.

Another approach by Wang et al. (2022) utilized the GENI platform as a contained applied testbed to facilitate learning cybersecurity concepts. The authors put forth EdGENI as a methodology for increasing the ease of use on virtual platforms to develop cybersecurity skills. The authors demonstrated utility in the approach for related disciplines, such as computer science, blockchain, and cybersecurity. They also discovered empirical data that users found EdGENI user-friendly and helped students learn the required concepts (Wang et al., 2022).

Educating faculty has been addressed in the literature due to the field of cybersecurity growing and maturing. Burrell et al. (2019) presented an approach for better educating educators called microteaching. One limitation of the literature on microteaching research was the aim of new instructors. Significant concepts of going over examples, simulated experiences, and similar methods were not applicable in all entry-level scenarios nor suitable for experienced faculty transitioning into teaching a new topic. With the development of cybersecurity teacher education programs, the demonstrated concept was relevant and helpful in those programs (Burrell et al., 2019). However, teaching the teachers was not an element heavily covered in any relevant guidance documents.

Ruiz (2019) conducted a study focused on secure software development in the undergraduate curriculum in the UK and looked at required cybersecurity content in 100 different computer science courses. The lack of consistency was surprising, with 40% of the courses considering the cybersecurity element optional and 6% leaving cybersecurity out of the curriculum entirely. The author argued that more courses on cybersecurity were not the solution to building a safer world but training information technology practitioners and computer science programmers from the beginning to promote safe computing concepts (Ruiz, 2019). This distinction was important when considering and contrasting against the various curricular guidance and certification requirements.

There have been efforts to create a taxonomy of approaches to cybersecurity education. However, a study by Crick et al. (2019) contradicted Ruiz (2019), who stated that depth was just as critical as breadth in cybersecurity education. The study justifiably identified that cybersecurity as an academic topic had pre-dated the abovementioned guidelines and recent literature. However, the maturing of the field must lead to the continuous re-evaluation of what should constitute cybersecurity education. Noting academic approaches to teaching cybersecurity, the authors identified cybersecurity as a discipline that benefited from a more applied methodology (Crick et al., 2019).

The study concluded that accreditation positively impacted cybersecurity within the UK. However, it was unclear what percentage of universities within the UK were accredited by the relevant body. Of note were the examples provided within the literature from participants who concluded that it was wrong to teach a computing curriculum without including cybersecurity issues (Crick et al., 2019). The recommendation to utilize industry standards and curricular guidelines indicated that the field requires further growth before utilizing a single baseline. However, it remained unclear whether a singular baseline would result from the maturing field.

Additionally, there has been an effort to develop a more standardized baseline regarding what should constitute cybersecurity education. For instance, Rashid et al. (2021) attempted to establish the Cybersecurity Body of Knowledge (CyBOK) in the UK to create a framework as a baseline. According to Nautiyal et al. (2022), CyBOK differentiated itself by not covering specific elements of required knowledge, offering foundational knowledge instead. Hence, it should be considered an augmentation with other methodologies and guidelines, not necessarily a standalone approach. Kohnke et al. (2022) presented a case study utilizing CyBOK in a security engineering course and found that utilizing the case studies required minimal additional work from the instructor.

Another trend in the literature pertains to sub-disciplines within the field of cybersecurity. The additional topics addressed the topic of cybersecurity but within the context of nation-states and national security. Cyberterrorism was a constant topic. Follis and Fish (2020) asserted that the intersection of hackers and the state exists, though it can be unstable and open to contingency. Furthermore, Dawson et al. (2018) demonstrated that the growth of the IoT enabled cybersecurity threats perpetrated by the hyperconnectivity found in these devices and others constantly on platforms. The critical element of this chapter was not that cyberterrorism or nation-state hacking was new but that the laws and regulations surrounding were are a critical element of the educational background of a cybersecurity professional and, as such, should be considered for inclusion in any academic program.

The COVID-19 pandemic further drove the literature to discuss cybersecurity education in university programs in the context of national security. Indeed, the pandemic generated a significant shift of programs moving online, with a noticeable shift to cloud or remote-based activity. While challenging, the case study completed online coursework and labs in cybersecurity while further developing partnerships to strengthen programs to meet national security needs (Dawson et al., 2021). Notably, the COVID-19 pandemic drove a significant increase in literature on online initiatives. However, it was impossible to determine if increased higher education online programs caused these initiatives.

Parrish et al. (2018) developed a paper showing that the maturing of the field has led to the identification of two future approaches to developing undergraduate programs. First, institutions can enhance existing programs with cybersecurity content and develop complete cybersecurity programs as standalone initiatives. The working group at the ACM Conference on ITiCSE noted that many standards are emerging to define what a cybersecurity education includes. However, the standards mentioned in the literature did not constitute a unified basis for any program development or revision, much less the niche of a liberal arts computing program.

Parrish et al. (2018) also established the consideration of the cybersecurity discipline over the long term. Just like computer science later expanded into multiple independent disciplines, such as engineering, information technology, and other fields, cybersecurity could establish its collection of related disciplines over time. Presented was the concept of a multi-disciplinary initiative, the proposal focused on the concept of cybersecurity being used to create a multifarious cyber science major. Envisioned was a broader cyber program combining the CSES2017, the ABET criteria, and the National Security Agency (NSA) Center for Academic Excellence approaches. This concept paired well with the earlier ITiCSE research, projecting that cybersecurity would become a collection of related disciplines (ABET, 2018; Blaine et al., 2021). The multifarious aspect required a much broader approach than strict cybersecurity. However, everything started with a security baseline. Nevertheless, Parrish et al.'s paper did not present material on the application to different program types, so assumptions existed regarding the needed flexibility and possible benefits from programs other than dedicated undergraduate cybersecurity majors at larger institutions.

Mountrouidou et al. (2019) showed that with a broadening of the definition of cybersecurity education, there had been additional recognition for diversifying the people involved. The ITiCSE 2019 working group identified a lack of diversity in professionals working in the field (Mountrouidou et al., 2019). The paper proposed various methods of enhancing diversity in recruiting underrepresented minorities in cybersecurity programs and how these efforts would improve with more targeted measures. The emphasis was not just on the lack of qualified professionals to fulfill cybersecurity-related job openings since the field and profession suffer from the reduced viewpoints offered by a more diversified group, including academic programs and the current workforce.

In the research conducted by the Cyberpaths project, Mountrouidou et al. (2018) focused on a better understanding of what attracted students to a program and what methodologies were of continued interest. Students at the university who completed the project were the main participants, but student pre-test and post-test surveys generated the resulting data presented in the article. By understanding the student interests, faculty could apply these data points to their programs.

The related trend was to integrate cybersecurity into cross-disciplinary programs. Payne et al. (2021) developed an example program with information technology, engineering, business, computer science, criminal justice, and philosophy, further expanding the discipline within university programs. The authors tied cybersecurity and general educational outcomes into a program with increased enrollment. One of the elements that the authors found exciting was that they met their expectations in drawing non-majors to the topic and often attracted historically dissuaded students into those computing courses. The statistics showed a higher growth rate than previous in underrepresented minorities taking classes and tied together with the other research on increasing diversity within cybersecurity.

With the literature maturing, the development of curricula guidelines, and discussions on the increasing diversity of cybersecurity students, a related challenge was being addressed. While the focus of significant literature has been on too few students going into cybersecurity, the capacity to train current students was critical (Verma, 2021). The National Science Foundation (NSF) had funded work in a capacity expansion. Still, identifying faculty who would utilize their limited time to develop cybersecurity training skills was challenging for their research (Teresco et al., 2022; Walker, 2018; Worland, 1978). Walker (2019) explained that topics for inclusion in programs or examining the depth of a program came with serious resource considerations.

As applied to cybersecurity training, more significant reviews of gamification existed in the literature. For instance, Wu et al. (2021) assessed whether gamification had benefits. The study concluded that students in a gamification course performed better in password management, internet use, and information handling than their counterparts in lecture-based courses (Wu et al., 2021). Moreover, the study found no significant impact on the student's willingness to continue information security learning, contrary to the expected results (Wu et al., 2021). However, it demonstrated the feasibility and potential benefits of incorporating gamification into cybersecurity education. Cole (2022) further explored gamification by investigating the impact of capture-the-flag (CTF) style exercises in an introductory computer security course. The core finding was that student motivation was higher for the CTF-style exercises than for the more traditional ones (Cole, 2022).

The gamification approach in cybersecurity continued to expand and develop with students utilizing specific platforms such as CyberAware (Ward, 2021). However, scant literature had covered these tools, demonstrating that while there was a wide range of tools and platforms to utilize, there was little consensus on any standardization for undergraduate computer science or cybersecurity courses. Burrell et al. (2019) cited microteaching in a limited context as appropriate and valuable for faculty development in cybersecurity teaching. They identified that the increasingly diverse nature of the field of cybersecurity and broadly diverse approaches in content and courses made it challenging to determine best practices. However, another proposed methodology was that of microteaching (Burrell et al., 2019).

Additional literature has echoed the trend in the gamification of computing courses to indicate it as an effective technique in cybersecurity. According to Malone et al. (2021), gamification saw heavy engagement from students. However, one essential caution from this technique was that semi-structured exercises could mean the students did not find the intended solutions. While this approach could work in some instances, in other cases, potentially not meeting the learning objective could lead to student frustration.

The study concluded that more research was needed into gamification in cybersecurity education to determine if the study's negative aspects were with the program's implementation or the methods (Malone et al., 2021). The study by Malone et al. was of note due to the emergence and increase of gamification in the pedagogical context as a field that showed benefits. The study also addressed the limitations but did not expand well on the types of gamifications that might be more susceptible to unintended outcomes.

While graduate programs were outside this project's scope, considering developments was relevant. Since these programs derive their students from undergraduate programs, they must be aware of the developments to ensure they serve incoming and outgoing students. In addition, the concept of a pipeline originating from K-12 programs through the undergraduate programs of focus into graduate programs dictates their brief inclusion in the literature review for this study.

When the seminal work on cybersecurity graduate programs originated in 2014, those types of graduate programs existed, but the question remained if an increased focus was needed (Bicak et al., 2014). Bicak et al. (2014) noted that many of these programs’ foundations involved approaches originating from standards, such as governmental ones. The proposal was a framework for curricular changes proposing three specialties for cybersecurity graduate programs. The offered specialties were data analysis, cyber intelligence, and healthcare information security and privacy. The later literature has demonstrated the relevance of these particular foci as emerging sub-disciplines within cybersecurity.

Schaeffer and Olson (2018) published a paper on curriculum development regarding doctoral programs in cybersecurity utilizing frameworks such as presidential orders, the United Nations (UN), and the International Telecommunications Union (ITU), among others. The paper's core reviewed three frameworks and the differences in their approaches. Noted were commonalities that allowed for the development of objectives and curriculum. In addition to cybersecurity courses and other technical curricula, managerial coursework was deemed necessary at the doctoral level.

Literature on Ethics and Philosophical Developments and Trends in Computing

Another minor trend in the literature was on how to address the topics and role of ethical discussions in computing education. The seminal paper introduced the overall topic of social responsibility and how it interfaced with computer education by Nielsen (1972). The topic itself was not new, but the trend was that increased attention and effort had focused on the implications of technology usage and examples of both a positive nature of technology in society.

Burton et al. (2018) presented an approach like storytelling as a medium of instruction for computer science, which utilized science fiction to teach ethical theories and their applications in computer science. As presented, one of the core reasons for the approach was to utilize science fiction to help overcome the inherent biases students bring into the classroom. Storytelling has been a traditional medium to convey reality but disassociates from actuality (Burton et al., 2018). Burton et al. (2018) presented a course outline to be used by computing programs to foster a more profound integration of ethical concepts. The usage of science fiction was more engaging for the students, enhancing the learning process while achieving the intended outcomes (Burton et al., 2018).

Terms and phenomena such as fake news have driven further attention toward the topic (Michaelson et al., 2019). While the specific example of fake news was not considered a new phenomenon, the utilization and enhancement of technology are relevant within computing programs. Fiesler et al. (2020) closely examined the concepts in a recent qualitative study. The authors studied 115-course syllabi from different university ethics courses to baseline the extent of ethical content implementation within these programs. Interestingly, over half contained topics on social justice, and one-third related to civic responsibility and misinformation (Fiesler et al., 2020). According to Ferreira and Vardi (2021), the trend was to include more discipline-specific ethical questions posed to undergraduate students and force them to think more deeply about social justice

These social conversations further elevated the topic to one consistent while not dominant in computing education. One approach suggested by Horton et al. (2022) advocated integrating ethical discussions as segments of other computer science courses. The most significant weight of the approach was formulated and developed with an interdisciplinary team composed of researchers and teachers with computer science and philosophical experience. The authors also explained that they could not discover any quantitative studies on ethics education in a computer science context. Nevertheless, the students received positive results, and the study reasonably accounted for the study's overall validity limitations.

Furthermore, the authors made their work open-source and fully available to others, which could lead to broader adoption of the material or techniques as a greater audience would be able to review and possibly adopt them (Horton et al., 2022). Moreover, Aggarwal and Ranjan (2022) suggested another approach was utilizing algorithms in the specific context of posing and fostering discussions on ethical issues in computer science since there was little research on integrating student viewpoints into curriculum development due to the inherent complexity of the topic (Aggarwal & Ranjan, 2022). Moreover, Petelka et al. (2022) stated that the literature on integrating ethics into computing courses has not fully agreed on what the content should be or the timing of teaching that content. The authors also discussed the resources needed for integration and interdisciplinary approaches. However, while beneficial, they impact the time and effort of designing and possibly instructing a course. Prompts and creating supplemental assignments were two of the most significant challenges in the approach. Petelka et al.'s findings indicated that the trend and call for additional ethical content in computer science courses were not without challenges, particularly around integration into existing courses, possibly missing or compressing foundational ethical theory.

Also addressed by this approach was ethics in computer science trends. Klassen and Fiesler (2022) presented an application of using the fictional show *Black Mirror,* focusing on the intersection of computing and society, along with the misusage and unintended consequences of technology, as an exciting approach to merging the topics. The authors admitted that additional courses utilizing the material would be needed to validate the findings further. However, they felt that the approach and resulting student reactions justified further exploring the approach as an additional element in computing curriculum developments (Klassen & Fiesler, 2022).

Pillai et al. (2021) demonstrated that the tangent field of human-computer interaction (HCI) also explored the integration of ethics into the curriculum, utilizing health policy development and tracking associated with the COVID-19 pandemic. The study presented no definitive outcomes. However, the work offered an approach to investigating ethics in the context of HCI further.

Another developing trend within computing education was further integrating the developing field of the philosophy of technology. According to Coeckelbergh (2020), this field has implications for computer science, human-computer interaction (HCI), cybersecurity, and broader social implications. Von Schomberg and Blok (2021) described a particular trend within the discipline, looking specifically at the concept of innovation, indicative of the modern era. A vital element of the authors' discussion and argument was that it was a critical element to explore since economic factors have driven the debate on the virtual world and the value of innovation in the modern era. These researchers contended that exploring the meaning of innovation and understanding the historical context, such as innovation introducing change into an established order, was fundamental to the concept of responsible innovation. Their argument further developed and explored the topic of the social good in technological education, albeit from a more philosophical perspective.

Blok (2021) further expanded on these original concepts in a later paper, clarifying the difference between technology and innovation by arguing that an act of innovation creates technology. However, innovation itself does not necessarily require technology. His explanations fostered a discussion on innovation and its relationship to technology, helping provide a framework for understanding the world (Blok, 2021).

Astola et al. (2021) refined that the work relates to undergraduate education because there was an expectation that graduates within the field utilize technology or innovations and possess the potential to create them. Another piece described the importance of innovation. It should not be considered simply a means to a particular end but a valuable human activity (Astola et al., 2021).

Literature on Liberal Arts Computing Education Developments and Trends

Within the specific context of liberal arts computing education, it was essential to remember that the field, and discussions on its inclusion within liberal arts, have existed at least since the seminal works published by Worland (1978) and D'heedene (1982). The merit of revisiting pertained to how the literature has shifted from the effectiveness of making room for computing programs within a liberal arts program to the larger context of embedding computing and related fields, such as cybersecurity, within undergraduate programs. Defined degree programs remained a core element, but this was critical because computing education needs to support students directly in their programs, facilitate the trend, and push towards integrating into cross-discipline or general education requirements.

The more modern trend concerning STEM, comprised of science, technology, engineering, and math education, has led to other literature on the compatibility and applicability of a liberal arts computing program. For instance, Dekker (2020) stated that the context was precisely placing STEM within liberal arts to achieve the cross-disciplinary education that would enable students to navigate better the trade-offs and conflicts that came from technological innovation and development.

Dekker (2020) further elaborated, stating that studying only one discipline gives a student a general perspective. In contrast, a course of study involving more than one discipline can facilitate different aspects and provide different or unique perspectives that advance study or knowledge in that field. As such, STEM topics cannot be independent of the arts. Conversely, the arts cannot be relevant in the modern world without STEM topics.

Zucker (2019) presented that an excellent example of growth in cross-disciplinary initiatives within computing with a liberal arts emphasis could be creating a course on robotics at a liberal arts institution. While, traditionally, this course would be highly technical, involving engineering, computer science, and possibly cybersecurity, the developed class would mix students from other disciplines. The unique element fostered was transferring knowledge from non-engineers to traditional engineering students since both perspectives gained more from the course. Thus, the literature demonstrated that computing concepts could be valuable and relevant to students from any discipline and worth consideration in a general education curriculum.

The most direct development in computer science education with a liberal arts focus was the ACM's special interest group SIGCSE's development of a Committee on Computing Education in the Liberal Arts (SIGCSE-LAC) in 2016. According to Baldwin (2018), while there was an expected variety in how liberal arts institutions developed their programs, enough commonality was discovered to continue the committee as a distinct subgroup within SIGCSE. In addition, while defining liberal arts computing, the committee examined other literature and member contributions.

The draft report rejected any definition of liberal arts that excluded computing disciplines as overly narrow and not aligned with modern educational needs. Baldwin et al. (2019) expanded on that report by asserting that building awareness of the academic discipline in the context of the liberal arts was a fundamental goal within SIGCSE, as the broader literature had demonstrated a trend toward cross-disciplinary computing educational outcomes as a core strength of a liberal arts education.

Teresco et al. (2022) further developed the work based on the initial report to the SIGCSE community, which built a body of work by inviting liberal arts institutions to submit curricula and innovations. A total of 18 institutions submitted material, allowing for creating a more definitive piece of literature with a wide variety of supporting elements. The produced literature resulted from the material collected from three years of liberal arts SIGCSE-TS affiliated events. While there was a wide variety of ways computing programs at various liberal arts institutions existed, it was possible to distill them into three core themes: 1) flexible pathways to the degrees, 2) cross-disciplinary initiatives, and 3) preparing students for a wide range of careers and entry into the workforce. Walker (2018) also collected many of these elements in a text published in 2018.

Flexible pathways was a newer term that was relevant in the context of liberal arts computing programs, describing an approach to facilitating completing a computing program within three years at many institutions. There was varying reasoning used for the approach, as factors such as delayed declarations of the intended degree, limited resources resulting in the periodic offering of courses, and scheduling conflicts with other departments due to the cross-disciplinary nature of the programs (Teresco et al., 2022).

Fee et al. (2017) identified a trend in liberal arts computing programs to facilitate flexibility by identifying tracks within a degree program. Moreover, Teresco et al. (2022) defined *flexible pathways* as allowing for a mix of electives while supporting interdisciplinary initiatives, such as minors, double majors, and other curricular activities, upholding the liberal arts philosophy of a broad education. A core curriculum set was utilized for a major but allowed for concentrations in specific areas in this approach. The concentrations covered were cybersecurity, game development, and the more traditional computer science and information technology specializations.

The core curriculum approach with specific concentrations was a potential method to facilitate the quicker introduction of new concentrations, typically enhanced with some form of a senior capstone project driven by the student's interests and goals. The senior projects were not limited to programs structured around a core but in conjunction with many different institutions' submissions. However, the noted was the limitations of the core curriculum approach.

Specifically, covering additional options in available courses, visiting faculty, and potentially overlapping course content could impact the predictability found within programs. It also increased the number of unique course preparations per semester with limited faculty to facilitate them (Teresco et al., 2022). With previous literature emphasizing the limited resources typically found in this institutional type, increasing the number of unique course preparations per semester further limited the ability of faculty to explore and introduce new topics and teaching modalities and limited the number of additional sections of popular courses.

With the cross-disciplinary focus of liberal arts programs, including topics from other majors within computing programs was a recurrent trend. Conversely, including computing courses in majors found in other fields was possible. While discussed as a benefit, a gap in the paper presented by Teresco et al. (2022) was that it did not address the additional load-supporting that other disciplines might place on the faculty charged with providing computing-related majors and minors. The flexibility facilitated minors from computing programs and computing-related tracks within different fields, such as business (Teresco et al., 2022).

This line of discussion also resulted in another gap where the current literature had not addressed whether encouraging students to collect additional majors and minors was a net benefit compared to the cost and time associated with further study. The original report by Baldwin (2018) and a subsequent paper by Teresco et al. (2022) failed to address the gap. The report and the literature support the cross-disciplinary benefits of a liberal arts approach in undergraduate education. Still, the gap remained as to the benefit level compared to those additional cost and time factors. Walker (2019) found this omission concerning due to an apparent push for programs to be all things to all people while failing to address the impacts on workloads adequately.

Teresco et al. (2022) also noted that when contrasting with the broader body of literature about the development of undergraduate standards, very few computer science programs at liberal arts institutions were ABET-accredited. Most programs that had their material reviewed by the committee considered the ACM curricular guidance their primary reference point. Due to the publication date of the undergraduate guidance, the institutions would have indicated the CS2013 ACM guidance revision instead of the CS2020 guidance for undergraduate programs. The development of the ACM/IEEE CS2023 guidance was currently underway, although a draft was available (Kumar & Raj, 2022). The guidelines split the curricular and process recommendations. New efforts and research were underway as there has not been an update to the computer science curricular guidelines since 2013.

As part of that work, the ACM/IEEE 202X Task Force collected material to supplement the guidelines from various groups to broaden the viewpoints and applicability of the curricular guidelines when published. An example of the incorporation of developing research and literature in the field. Preparation had commenced for the next revision to develop a process for liberal arts computing programs to incorporate the CS2023 curriculum guidance into a program review or revision (Barnard et al., 2022). The developed process intended to provide a methodology for reflection on institutional goals and how to utilize official curricular guidelines. Nevertheless, a gap remained in the literature regarding what institutions have been using as a baseline if it exists.

The context of the SIGCSE's Committee on Computing Education in the Liberal Arts was a part of the ACM special interest group on computer science education, limiting the contributing institutions that actively engage with the ACM. Potentially even more limiting, the institutions must also engage with the liberal arts committee itself. This limitation may result in self-selection and a skewing of applicable liberal arts institutional data collected toward institutions more proactively developing and maintaining their computing curriculum. A presumption existed that sufficient transference exists due to the demonstrated partnerships of the ACM/IEEE in developing their curricular guidance documents. Though often hindered by the smaller resources available to most liberal arts institutions, a desirable goal to completing a degree was that of *flexible pathways*.

Summary

Cybersecurity education was a developing field with more guidelines and goals than proper curricular guidance. As the topic has existed for several years, many industry standards have suggested educational requirements. The literature has shown various choices regarding guidelines on how curricular designers and instructors have interpreted these requirements. The additional context of a liberal arts institution has shown little research on how the various approaches and methodologies have implemented cybersecurity curricula in liberal arts institutions, nor has it been studied regarding integration into undergraduate general education requirements.

Considering the overarching goal of holistically developed individuals who can “think, learn, be creative, and adapt to change,” the literature supports liberal arts as a solid foundation for these outcomes (Detweiler, 2021, p. 31). Moreover, support was demonstrated for the emphasis on broad, cross-disciplinary initiatives in liberal arts programs by general undergraduate education and computing education trends. Indeed, the 2020 computing paradigms report consolidated these trends and mentioned the need for and growth of CS+X or

X+CS curricula as being significant in the future of undergraduate computing programs (CC2020 Task Force, 2020). Computing programs were also well-positioned in terms of trying new pedagogical approaches, and the gamification approach was presented by many authors as a potential approach to computing programs, even for cybersecurity specifically. Ethics and philosophy were less direct, but constant occurrences were found within the literature and warranted attention in a literature review for a study of this nature.

The remaining gap was between impressions or a general understanding of what liberal arts was, which leads to the idea that any discussion of educational programs within a liberal arts context must start with a definition (Stross, 2018; Teresco et al., 2022). The need to spend space within any paper discussing the liberal arts for the sake of definition was an inherently limiting factor, reducing time and space for the literature's actual focus. This specific context fostered curricular innovation concerning computing programs and was a forced development due to the constrained resources in this type of institution.

The literature did not overly clarify what liberal arts should be considered, even if mildly differing in the phrasing found in the literature. The limitation of literature on liberal arts was that almost all literature on a topic in this context tends to include an explanation of the author's definition of what that piece of literature considered the liberal arts to be. These definitions require space in a non-liberal arts context that should be utilized for additional material supporting the overall purpose, potentially reducing the space to discuss or otherwise present the overall concepts.

However, even in the broader context of cybersecurity education, the trend was toward developing it as a collection of related fields versus a sub-field of computer science. The distinction was essential as independent academic disciplines can be better targeted for different pedagogical approaches, tracked, and identified directly, eliminating possible variables when researching applications such as educational outcomes.

The literature concludes that a cross-disciplinary approach was an overall trend and a modern need. However, there was a gap in the literature on how to facilitate cross-disciplinary cybersecurity education in liberal arts programs. The most significant gap in the literature was what should constitute an undergraduate cybersecurity curriculum, which only loosely discussed standard baselines regarding guidelines and accrediting sources.

Additionally, the literature failed to bridge the liberal arts cross-disciplinary focus, the general trend in computing education to focus on cross-discipline topics, and how to integrate cybersecurity within a program comprising these elements. Finally, the literature was definitively inconclusive on what could constitute a baseline for cybersecurity programs as a whole and, even more significantly, whether a unified baseline for cybersecurity undergraduate programs was desirable by liberal arts programs outside of the justification for the inclusion of individual elements from a baseline. The lack of agreement in the literature implied that early-stage innovators must utilize new baselines through the lens of the DOI.

Still, most liberal arts computing programs did not have the time or resources to use guidelines originating in 2017 as the basis for cybersecurity programs, so it remains unclear what, if any, baseline should or could be used in a liberal arts computing program when investigating cybersecurity concepts (Joint Task Force on Cybersecurity Education, 2017). The next chapter examined the project's methodology and placed it into the context of hermeneutic phenomenology. The chapter also provided reasoning for approach, population, data collection, and analysis.

Chapter Three

Procedures and Methodology

Introduction

Liberal arts institutions often focus differently on their programs than their larger research-based counterparts (Teresco et al., 2022). While there was curricular guidance surrounding the cybersecurity curriculum in undergraduate institutions, there was little to integrate cybersecurity into the unique opportunities that liberal arts computing undergraduate programs offer. Unanswered by previous works was how to use curricular guidance in a liberal arts context. This project was qualitative hermeneutic phenomenological research examining cybersecurity adoption in liberal arts computing programs. Liberal arts programs can utilize the completed research to make evidence-based program revisions and development decisions. By focusing on the past and current state curriculum and having explored the reasoning and justifications behind the participants' experience, the project tangentially addressed the broader liberal arts student outcomes and program-level goals.

The emphasis on lenses enhanced the understanding of the phenomenon (Peoples, 2021; see also Gadamer, 2004). The primary lens utilized in this project was the DOI, as expanded upon in the theoretical framework section and literature review, and phenomenology was considered the grounding framework.

Research Method and Paradigmatic Perspective

Overview of Methodology Selection

According to Peoples (2021), the hermeneutic circle, which views research as a revisionary process, was the core consideration. This approach to the project allowed the development of an understanding of the lived experience of the participants while appropriately viewing the project through the most appropriate grounding philosophy or theoretical framework that revised interpretations develop.

The research questions drove at those with experience with computing programs in liberal arts institutions. Qualitative hermeneutic phenomenology was a more robust approach in this instance than a quantitative approach due to the focus on discovering questions versus discovering answers to specific questions. The project provided more evident results by documenting, interpreting, and revising the participants' lived experiences. Those results are how in undergraduate programs: what the intended outcomes might be and how they might differ from institution to institution; the selection of topics and how that might vary from institution to institution, and the learning environment.

Qualitative Research Approach

This project considered both quantitative and qualitative approaches to research design. Traditionally, information on curricular implementations has been quantifiable. Previous studies, such as the one by Abu-Taieh (2017), explored numbers, programs, and highly defined questions on objectives, outcomes, and terminology. Quantitative surveys and scales would have been highly limiting in potential data collection and thereby overly skew the analysis toward personal experiences. Since the lived experience of the participants was the project's focus, the exact answers to questions were ill-defined, allowing for a richer exploration. The interview questions were only semi-structured and allowed for approach flexibility. According to Dibley et al. (2020), the interviews enabled participants to narrate their experiences, revealing the studied phenomenon.

By taking a phenomenological qualitative approach, this project aimed to capture a better understanding of the individuals' lived experiences to understand what the historical context might be and the justifications for the current state of their programs. Newer methodological developments were considered, such as postphenomenology, as it focused on blending the philosophy of technology with the philosophy of phenomenology. However, this approach was deemed inappropriate for an initial project focusing on the human experience with a technical subject versus the human experience with technology (Ihde, 2009). Ihde (2009) proposed an approach that mostly refuted the supposed romanticism associated with Heidegger and focused on blending hermeneutics, pragmatism, and phenomenology (Coeckelbergh, 2020). Zwier et al. (2016) provided further criticism and support for postphenomenology rejection found in the literature discussing its empirical nature precludes phenomenological questioning.

As presented by Peoples (2021), two prevailing types of phenomenological research were reviewed and considered grounding philosophies: Husserl (1931) with transcendental phenomenology and Heidegger (1971) with hermeneutic phenomenology. The theoretical framework significantly impacted the project in selecting this qualitative methodology. In a phenomenological project, the theoretical framework was always phenomenology (Peoples, 2021). Hermeneutic phenomenology explicitly supported the usage of lenses to view the project, though to enhance one's understanding of the phenomenon (Peoples, 2021; see also Gadamer, 2004). That philosophy and approach allowed for utilizing technological framework theories without impacting the fundamental approach found within hermeneutic phenomenology.

The primary grounding lens utilized in this project was the DOI theory, which allowed the project to be grounded in phenomenology while also viewing the results within that theoretical framework to give additional context. Phenomenology was then considered the grounding framework and the utilization of the term lens. The combination of phenomenology and the DOI allowed viewing the project participants' live experiences without the additional considerations that postphenomenology would have required. A critical consideration was that phenomenology, specifically hermeneutic phenomenology utilized in this project, was a philosophical grounding framework and a methodology for collecting data.

Overview of Information Needed

The core research questions explored the lived experience of faculty or curriculum designers in liberal arts institutions and how they have adopted cybersecurity within their computing programs. The project explored the methodology they have utilized and if there are any particular elements of curricular design or cross-departmental integration with the cybersecurity elements from their programs.

The second research question explored the lived experience in the context of adopting cybersecurity concepts outside of computing programs. The exploration gathered the reasoning and methodology for how far cybersecurity had permeated through liberal arts institutional programs by looking at general education curricula and whether cybersecurity elements were present. Additionally, this question helped establish whether liberal arts computing programs had adopted cybersecurity and if the adoption of cybersecurity concepts into liberal arts undergraduate degrees exists. State and national initiatives have been pressing for cybersecurity education in K-12 programs, the workforce, and higher education institutions. Still, it was unclear the extent of adopting those cybersecurity concepts into the broader general education curriculum or what the experiences of faculty and curricular designers might have with that.

Sampling Procedures and Data Collection Sources

Research Sample

The population for the qualitative project was faculty members in liberal arts computing programs. The sample was recruited from members of the SIGCSE Committee on Computing in Liberal Arts Colleges Listserv, the SIGCS-TS affiliated event, and the SIGCSE-Members Listserv. The recruitment of participants utilized both purposive sampling and the snowball method, where participants recommended other potential participants to gather a selection of twelve individual educators from a minimum of four different liberal arts institutions. The basis for formulating the minimum target of twelve participants originated from Braun and Clarke (2016), who asserted twelve as the point of minimum saturation. Lincoln and Guba (1985) further supported that minimum value, concluding that achieving sufficient information redundancy equated to saturation. As such, this project set a target pool of twelve participants, while recruitment was placed at seventeen to allow for attrition, incomplete interviews, and pilot testing. While the solicitation was via the SIGCSE Committee on Computing in Liberal Arts Colleges Listserv, the SIGCS-TS affiliated event, and the SIGCSE-Members Listserv, a pre-interview survey was utilized to capture demographics and allowed for insight into the number of institutions, institutional size, and observed sex of the participants. The project's original intent was to have two cybersecurity faculty members and two curriculum development faculty from each institution based on the classifications of type and institutions entered into the pre-interview survey.

The project obtained site permissions for the SIGCSE Committee on Computing in Liberal Arts Colleges Listserv and SIGCSE-Members Listserv. Sent out to that list was a recruitment email to all subscribers. The project accepted educators who met the qualifications of being a liberal arts faculty, curricular designer, or both. Those educators originated from the Association of Computing Machinery, Special Interest Group on Computer Science Education. That group had a Computing Education in Liberal Arts Colleges Committee, abbreviated as SIGCSE-LAC, that provided the core population but was scalable if an institution or faculty member had withdrawn or was otherwise unavailable to complete the project and offer valid candidates pilot testing questions.

Resources in liberal arts institutions were often considered limited, with faculty holding more than one position. A presumed limitation of the project was that specific role definitions at institutions such as instructor or curriculum designer were likely to be combined for participants and therefore needed to increase the number of institutions to ensure sufficient variation while keeping the participant sample size between twelve and sixteen individuals. While initially envisioned as being four for each role of faculty and curriculum designer individuals from four different institutions, that goal proved unachievable. The project used a revised methodology that removed the institutional target number to accommodate a focus on the total number of participants and set the maximum of individuals from a single institution to four. As such, this resulted in almost every participant in the project being from a unique institution.

Data Collection Methods or Tools

The materials obtained from the participants of this project were limited to the information obtained from the initial demographic survey, observed factors such as sex, the content of the primary interview, and any applicable follow-up interview. No other material was requested or accepted for the project from the participants.

The material collected comprised recordings of live video interviews, transcripts generated from those video interviews, and pre-interview survey results, stored in a cloud drive

(Dropbox) and further secured via two-factor authentication. Data processing with the third-party tool Scrintal utilized the most stringent security standards. Each participant and referenced institution were randomly assigned an ID number accessible to the researcher, and only anonymized, and aggregated data was shared. No non-anonymized data was shared with other entities before, during, or after the project. The peer-review checking of transcripts and coding was with the anonymized data only. Per university policy, preservation of recordings occurred until the project's conclusion, and there was a retention period of three years for the transcripts. The data collection period was from January 25th, 2022, through May 13th, 2022.

The data collection process began with a solicitation from the SIGCSE subcommittee on Computing Education in Liberal Arts colleges Listserv, the SIGCSE-TS affiliated event, and the SIGCSE-Member Listserv to develop the pool of selected participants. Responses to that solicitation received a pre-interview survey comprised of basic demographic information, identifying information for classification, and documentation of informed consent delivery. The pre-interview survey was a Microsoft Form to collect the initial information for interview scheduling on a website. It also contained the IRB Approval, Consent form, and other relevant documentation that was fully available for the participants. Participants must have read and agreed with the consent form and agreed to a full interview as part of the sign-up process in the demographic pre-interview survey.

Participants originated from the pre-interview survey based on meeting the qualifications, which removed any individual who did not meet the criteria or were unwilling to schedule a full interview. Participants were accepted until information redundancy became apparent at the minimum of three pilot test participants and twelve project participants (Lincoln & Guba, 1985). Initially, consideration for balancing out curricular designers and instructors was an objective.

Still, no participant signup had selected anything other than when addressing that question in the pre-interview survey. Once selected, participants were requested to sign up for a time to participate in a recorded interview via Zoom of approximately 60 minutes. The video interview selection allowed for the exchange of verbal and non-verbal information during the interviews (Paulus & Lester, 2022). The interviews were semi-structured to facilitate full exploration of the experiences (Giorgi, 1985). As part of the process, journal entries about the interview and any additional insight gained from the individual interview post-interview. Hermeneutic phenomenology emphasized making personal bias explicit, which journaling provided an opportunity to do as a methodology to reduce their impact or impressions of the lived experience that was the project's objective (Gadamer, 2004). This cyclical approach provided the effect of temporary brackets that undergo refinement cycles in the understanding (LeVassleur, 2003). It was essential to consider that bracketing was an approach in transcendental phenomenology and that hermeneutic phenomenology, which was the philosophical foundation of this project, accomplishes this narrowing down of data through reflection on the themes and experience (Neubauer et al., 2019). Notes were taken during the individual interviews to cross-check with transcriptions. Journal-like notations on those interview transcripts in post-interview settings provided an opportunity to capture any resulting ideas relevant to the compilation of data for the project.

With the revisionist nature of hermeneutic phenomenology, follow-up questions for specific participants were accounted for as possibly needed. Participants understood that any follow-up would have been via Zoom or email and appended to the original interview transcript. However, follow-up questions were unnecessary as the open-ended nature of the semi-structured questions allowed for a sufficient understanding of the responses. The interviews were transcribed automatically via Scrintal and exported with timestamps to result in a manually confirmed transcript of the interviews. Scrintal was a web-based transcription platform fully compliant with the more stringent data security standard General Data Protection Regulation (GDPR). Automatic transcription with a manual review facilitated software automation while ensuring accuracy and understanding of the data. The purpose of software automation was to assist in accelerating the process. This acceleration allowed most of the time and effort spent on the analysis portion. Nevertheless, the manual review granted confidence in the accuracy of the source data for that analysis. Manually sanitized and edited transcriptions were imported and stored within the Computer-Aided Qualitative Data Analysis (CAQDAS) software tool, MAXQDA, for data analysis and coding.

The transcription process allowed for data immersion and a more profound understanding and began to develop insight into what data was collected (Vanover et al., 2021). While there are differing opinions and approaches to creating transcripts, namely exact transcription and a more narrative approach, the selected method was closer to exact transcription with minimal editing for the initial transcript creation. Albeit, editing out filler words such as um, ah, and you know, made it more readable and comparable so that it constituted a narrative approach (Vanover et al., 2021). Ensuring that this approach was relatively standardized for all interview transcripts was essential. Vanover et al. (2021) state that all "words, gestures, and other aspects of discourse are always rendered from a particular set of biases and beliefs" (p. 72). That was the justification behind a cautious approach to editing the initial transcripts. Questions asked during the interviews were structured to facilitate the participant to answer in their way to reduce bias. However, to further reduce any potential impact of bias from being introduced, a minimum amount of editing was done before later revisionist steps reduced the impact on the creation of the transcripts.

Data Analysis

The coding and theming of data were done primarily in a manual fashion. The coding process took place within the MAXQDA tool, but there were no automatic coding efforts. Phenomenology strongly emphasized staying close to the data, so overly automated coding was not recommended (Peoples, 2021). It was important to note that MAXQDA was merely a tool and not a coding system in and of itself. However, the time difference between manually coding outside a system and utilizing the tool was negligible for this project scale. Therefore, the primary usage of MAXQDA was organization, processing transcripts for initial editing, and manually cleaning up transcripts generated from the audio recording with timestamps generated via Scrintal. The creation of the codebook took place within MAXQDA. The only analysis stage usage was to digitize a manually created coding system to organize resultant data. The project spent significant time developing and refining the coding choices, as poor or insufficiently thought-out choices could hinder the qualitative analysis (Vanover et al., 2021). The coding creation process centered around an inductive process, letting the themes emerge while reviewing the data. Inductive could be more time-consuming than deductive but allowed for a more natural and accurate coding system. Beginning with a deductive approach was decided against, primarily because it would have overly structured the data and would have potentially hindered the discovery of an unrecognized theme. Bingham and Witkowsky (2021) suggested a cyclical method alternating between the two approaches. However, starting with the deductive process did not fit the philosophical approach.

In addition to coding, there was the conscious decision to include thematic phrases applied to selected data units. This approach aimed to identify what the data was about or meant (Miles et al., 2020). Miles et al. (2020) mentioned that researchers could first code their data and then group those codes via thematic elements. That was the approach selected for this project. First, the project utilized an inductive approach for coding the data. Then, following the hermeneutic cycle of revision, the project grouped those codes based on any common themes that emerged. Finally, the project developed a thematic statement describing the elements refined and distilled from the original transcripts. Saldaña (2021) pointed out that during coding, researchers should pay particular attention to anything that surprised, intrigued, or disturbed them.

A modified van Kaam method facilitated a detailed data analysis (Moustakas, 1995). This method comprises the following steps: Listing and grouping, reduction and elimination, clustering and thematizing, validation, individual textual description, individual structural description, and phenomenological situation reflection (Moustakas, 1995). Quantification of the resultant themes allowed for further analysis. Corroborative data that supports qualitative analysis is known as paradigmatic corroboration (Saldaña, 2021). A custom MySQL database facilitated the creation of demographic charts, and SQL report scripts were written and developed for the project.

Limitations of Project

A potential limitation to the project was the primary pool of participants recruited from the ACM special interest group on Computer Science Education. There was the potential of missed individuals originating from institutions of a liberal arts nature that did not engage in activities with the ACM may have been missed in addition to those same institutions that engage with the ACM but not the subcommittee on Computing Education in Liberal Arts colleges. The limitation was somewhat mitigated by soliciting the greater SIGCSE-Member Listserv but was still present. The snowball recruitment method further reduced any difficulties in recruiting but introduced a slight risk of narrowing the scope. That risk was mitigated by capturing the region of the institution to classify the institution anonymously but demonstrated differences that were present.

The project's primary ethical consideration was protecting participants' privacy. By holding a high standard of confidentiality, an assumed delimitation of the participants that the questions posed had truthful answers. It was mitigated to the greatest possible extent, thereby enhancing the inherent trustworthiness of the resulting data analysis. Any identifying statements within the recordings were omitted or generalized in the transcription process to ensure participants' privacy. During the interview, the participants verbally reinforced the confidentiality aspect to reasonably state the separation of research and professional roles and explicitly distance where such intersections of roles existed. However, as per McGill et al. (2021), it was essential to recognize that the experiences, perceptions, and the intersection of the project are not mutually exclusive. Those were part of the researcher's social identity, made the data more genuine, and enhanced the truth found by the project (McGill et al., 2021). Journaling allowed for control and mitigation where bias could be perceived or introduced.

In order to enhance the trustworthiness and validity of the project, a neutral colleague provided cross-member checking. That colleague only had access to sanitized and anonymized transcripts, so a non-disclosure agreement was unnecessary. The objective of the cross-member checking, also known as peer-review, was to triangulate the data by asking questions about the methods, the resulting analysis, and the conclusions that emerged (Peoples, 2021). Modifications to the questions or transcripts were minimal. Where it was applicable, documentation of bias, real or perceived by either party, was noted in the post-interview journaling. A pilot test of the interview questions with three individuals took place, further refining the approach. The data analysis did not incorporate the data collected from the pilot test as it tested the validity of the interview questions. Those participants were removed from the project after revisions were incorporated.

Summary

The data collection methodology originated within the hermeneutic circle of constant revision and data review. The semi-structured interview tool allowed for a rich data collection methodology and enhanced the collected data. That data allowed for analysis to establish a clearer view of the purpose, content, and context. The project findings facilitated research-based evidence and justifications for program modifications based on how cybersecurity topics had been implemented or adopted at liberal arts institutions. The data transferability applied to liberal arts institutions in the context of how they may integrate cybersecurity into their curriculums. It was also potentially transferable to emerging topics such as blockchain and computing. Of a more abstract nature, there was also the potential for transferability to general undergraduate programs that are not necessarily liberal arts based.

There was careful consideration to the role clarity where the participants could perceive bias of professional relationships outside the project. Also documented were any segments with potential for bias to ensure that it was explicitly identified and accounted for, as complete separation was neither possible nor desirable. There was an inherent recognition that experiences and perceptions of the timing of the project were significant. According to McGill et al. (2021), those were all part of a researcher's social identity, accounted for, and made the data more genuine and enhanced the truth found by the project. That complex intersection of roles enhanced the data analysis's validity to capture a wider possible pool of participants. The knowledge of the likely scenarios of what the participants had experienced allowed for opening lines of discussion but kept interviews open to avoid steering the participants in any predefined or suggested set of responses, allowed for a richer exploration of the participant's experiences, and mitigated the potential perception or introduction of bias.

In the next chapter, the project findings were explored and analyzed. Participant demographics provided the makeup of those recruited for the project. Finally, presented were the themes that emerged.

Chapter Four

Research Findings

Introduction

Presented in this chapter were the project's findings and connection to the hermeneutic phenomenology grounding framework. Furthermore, the discussion within this chapter covered the participants, research settings, code creation process, temporary brackets, and themes. The project discussed student outcomes, curricular content, and programmatic level goals.

The chapter and the data analysis followed the hermeneutic cycle. The process involved cyclical coding, theme review, additional coding, journaling, and clarification. Changes were continually incorporated into the data and analysis, further refining the researched phenomenon (Hycner, 1999). Finally, the connection between the themes, phenomenological framework, and explored and documented was the applicability of the DOI lens to the project's findings.

Participants and Research Setting

One of the primary conditions that may have influenced the participants was the concept of role confusion due to meeting the same qualifications as the project's target population. Mitigating controls and the semi-structured nature of the interview questions were in place. However, the researcher had a similar professional role as the participants. It was a point of discussion made explicit to the participants as not being a driver of the questions.

The other possible condition that may have influenced the research was recruiting participants with individuals who were more engaged in the computer science education community. The region was added to the demographic information on institutions to ensure that participants were not overly skewed to a single area in case there was an unknown impact that region may have on liberal arts computing programs.

Table 1

Demographic Information Table presented by Experience

Factor Experience	Years in Role	Primary Title	Observed Sex	Institution Region
EXP01	15	Professor	Male	Midwest
EXP02	21	Professor	Male	Northeast
EXP03	20	Professor	Male	Northeast
EXP04	32	Professor	Male	Midwest
EXP05	4	Adjunct	Male	Northeast
EXP06	18	Professor	Female	Northeast
EXP07	2	Assistant Professor	Male	Northeast
EXP08	7	Associate Professor	Female	Pacific
EXP09	3	Associate Professor	Male	Northeast
EXP10	3	Assistant Professor	Male	Midwest
EXP11	3	Associate Professor	Male	Northeast
EXP12	47	Professor Emeritus	Male	Midwest

Note: All participants indicated having both curriculum designer and faculty roles.

Review of the Participant and Institutional Demographics

The project comprised a total of 15 participants. Utilized were three participants for pilot testing, and after revisions to the interview questions, they provided feedback that helped revise the questions utilized for the remaining participants. A total of 12 participants made up the remaining project. Another two participants had been recruited but failed to complete the demographic survey and sign up for an interview.

The term experiences described the 12 participants who facilitated the project, so the project utilized an EXP prefix to differentiate between the participants. That experiential focus was an essential distinction as it was the participants' lived experience being researched and not necessarily the participants themselves. Observed sex was also captured in the demographic information to compare against the national averages for individuals in the role of computer science instructor. The participant composition was 83% male and 17% female. Those metrics align with the national computer science professor statistics of 78% male and 22% female (Zippia, n.d.). While all participants indicated that they considered themselves both instructional designers and instructors, there was a wide range of years of teaching. The minimum time in the role was two years, a maximum of 47 years, with the mean value being 15 years.

Table 2

Observed Sex of Participants Compared to National Averages

Group	Male	Female
Participants in Project	83%	17%
National Average	78%	22%

Note: National Average of Computer Science Professors

Institutional demographics were also varied, allowing the examination of a broad set of experiences. When viewed by region, present were: Midwest had four, Northeast had seven, and Pacific had one. While regional factors could have impacted programs represented in more than one region in the project, the project judged that the institutional type of liberal arts was the most impactful factor. The institutional sizes also varied, with the minimum being an overall student body size of 950, a maximum size of 3,600, and a mean size of 2223.

Project Analysis

A cyclical process was used in the creation of codes and codifying themes. First, a primary observation, such as curriculum development, was coded. The process progressed to reading each transcript to code relevant sections with that code. The process then involved extrapolating any other journal notations and meanings from the transcripts and creating a new one. A review of each transcript then took place, looking for text matching the one code. Each of the ten themes followed this process. A frequency table and, individually, the dominant themes, denoted with an asterisk, have been provided.

Table 3

Themes and Presence per Experience

EXP Theme	01	02	03	04	05	06
Career-Prep	X	X				X
Cross-Disc.	X	X		X	X	X
Curr. Dev.	X	X	X	X	X	X
Eth. & Phil			X	X		X
Flexibility		X		X	X	
Mission & Values	X	X	X	X		X
Recr. & Retention						X
Resour.		X	X			X
Semantics & Term.		X				
Writing		X	X			

Note: Participant theme occurrence split into two tables

Table 4

Themes and Presence *per* Experience

EXP Theme	07	08	09	10	11	12
Career-Prep	X	X			X	
Cross-Disc.	X		X	X		
Curr. Dev.	X	X	X		X	
Eth. & Phil	X					X
Flexibility	X	X		X	X	
Mission & Values						X
Recr. & Retention			X			X
Resour.		X	X			X
Semantics & Term.	X	X	X	X		X
Writing				X		X

Note: Participant theme occurrence split into two tables

Theme 1 – Career Preparation

Career preparation was coded 11 times through the transcripts. The theme was positive and negative in the participant's experiences in the project. When examined, the theme emphasized the split view on the purpose of a traditional liberal arts education. More specifically, the conflict between a more classic view of pure learning to learn instead of a more holistic viewpoint or a career preparatory educational tradition.

The theme of career preparation was related to the earliest literature on computing subjects introduced to liberal arts institutions. D'heedene (1982) described computer science education in the liberal arts as comprising about two-thirds of liberal arts and sciences, and the remaining one-third as devoted to computer science courses. Multiple participants indirectly spoke on the topic and conveyed that defending the discipline took up a fair amount of their time. EXP08 stated that computer science "has rigor, new and different ways of thinking, and not just a pre-professional program and not just programming."

However, there were a couple of distinct instances of aversion to even cybersecurity as a term for their institution's computing program. EXP07 commented that their university included the concepts but would never utilize the term cybersecurity. "Cybersecurity, I think, has left some of our faculty with an impression that it was more career orientated." EXP08 also discussed a viewpoint that cybersecurity has a perception at their institution as overly professional and that creating an overt cybersecurity program would "be seen as too professionally orientated."

The nature of the theme tied it to the other theme entitled semantics and terminology. Not only was a fair amount of time spent still explaining and justifying computer science, but this carried over into newer disciplines, such as cybersecurity, that have developed out of it.

Table 5

Career Preparation Examples

Experience	Response
EXP01	There you know all the different types of organizations that provide a certificate. So talking with my students was interesting because some said, "Well, I do not have to have a certificate certification." What I tell my students is that this education is essential. Nobody can take from you, no matter what is going to happen. Nobody can take from you when you do. You know something. It is like music; if you are by yourself, you can listen to music. If you can play a piece of music, you are not alone anymore.
EXP02	I think culturally, in the US, we sort of have these stereotypes about technical trades or technical skills, and we tend to pigeonhole people too much. Moreover, maybe part of it is because computer science is still an infant from an academic standpoint. I mean, we are 65 years old, the engineering, the real engineering disciplines are thousands of years old, and so we are not. We are not very mature as a discipline. I think part of that is reflected by how people think of kids with a computer science degree. Oh, you are going to be a programmer all your life.

(continued)

Table 5 (Continued)

Career Preparation Examples

Experience	Response
EXP06	I think of information security as being a little bit like ethics and professional practice in general. Some of it should be in courses across your curriculum. We do have some of that, so our database course, you talked about, data integrity and, you know, SQL injection gets covered, and hey, you got to protect against that. I know the web development course talks some about permissions and setting up your environment and all of that. Programming. We definitely do very lightweight, and input validation comes up, so there are places where we sort of seed it, and I would not even necessarily say it hits the level of being a learning outcome.
EXP07	I am going to just be honest about my own prejudice here. Suppose I see a school offering a cybersecurity program. In that case, I think of that school as a little bit like more catering to what you call it professional adult education and less catering towards sending students to grad school.
EXP08	We actually have a cross-enrollment agreement with [a local school], I do not know, a few miles away from us, but they offer a cybersecurity class. Their curriculum is much more professionally [orientated], like the whole university's curriculum is much more professionally oriented than [ours]. So we would accept transfer credit for that course, but we have not really had any students take advantage of that opportunity.

(continued)

Table 5 (Continued)

Career Preparation Examples

Experience	Response
EXP11	So we have to do a significant amount of defending our discipline internally because everybody wants to jump on the cybersecurity bandwagon or technology bandwagon, and we even showed them a lovely diagram about it. I am sure you have run into it where there is cybersecurity, and then there is a very, very small bubble that's cyber forensics, on the bottom right corner, and then everything else is other concepts. So that was instrumental to making our administration understand.

Note: Minor editing for readability

Theme 2 – Cross-Discipline*

Coded 19 times through the transcripts was the theme of cross-discipline. The theme emerged in a variety of ways. However, it conceptually focused on integrating aspects of the computing discipline with other disciplines or bringing outside disciplines to computing-related courses. The literature also identified this trend in curricular guidance and examined various papers. Cross-discipline was denoted with an astrict due to being one of the top three coded themes.

Experiences varied depending on the university's structure and the individual program's goals. EXP02 phrased it as “we are not simply creating another computing-based academic program. We are trying hard to make this academic program much more holistic.” While not as overtly phrased in other transcripts, the mention of this trend and approach occurred more than once. In many circumstances, the topic expanded past cybersecurity into other computing subfields such as ethics, psychology, and philosophy. Notably was integrating cybersecurity curricular content into cross-discipline efforts, such as integration with criminal justice programs. Two different experiences at different institutions discussed criminal justice, demonstrating that it was not a unique opportunity but certainly a viable approach. That connection allowed for the utilization of existing expertise and allowed for the exploration of cybersecurity themes, topics, and viewpoints.

Curriculum development was a closely related theme when reviewing cross-discipline initiatives. There were many instances of the same transcription segment being coded with both themes to denote the dual nature of the statement of intentions. In programs where cybersecurity was not explicitly present, cross-discipline was one of the methodologies to help bring the topic into programs and maximize the usage of existing faculty.

Table 6

Cross-Discipline Examples

Experience	Response
EXP01	Now depending on if they are on the major, if the major is business and the minor in information technology. Students do have the option to pick some specific courses. They do not have to. It is optional. It is an elective. They do not have to go to the core because it is specifically for those in the management major.

(continued)

Table 6 (continued)

Cross-Discipline Examples

Experience	Response
EXP02	From the beginning, I was interested in making the program more holistic regarding the challenges and issues individuals and organizations face. Thus, I contacted the chair of political science and the Chair of sociology and criminology, and it is and said I would love to get your disciplines involved and create, helping me create a more holistic cybersecurity program. Moreover, after a few quick conversations, they were on board. The result of that is three concentrations within the major. There is a policy and law concentration that one leans heavily on the political science side of things. So they are taking courses on international relations and cybersecurity law and that type of thing. The second concentration is called Crime, Society, and Culture. So that is the criminology and sociology things. So they are learning more about deviance, what makes someone deviant, and their behavior. Right for me, from their criminology and sociology perspective, they study why people might become lifelong criminals versus someone who might commit a crime and then never do it again. And so there is that sort of perspective, and then the third concentration is called information systems and security. It is the technology-slanted concentration of the three. That one is more traditional in covering the tech-based topics you typically see in a cyber program.

(continued)

Table 6 (continued)

Cross-Discipline Examples

Experience	Response
EXP02	The holistic perspective is absolutely key. So we are a faith-based institution, and their mantra is sort of educating the whole person. They think of education very holistically. I really took that and said, okay, how can we apply that to the world of cybersecurity? Oh, let us get other disciplines involved. The result is that we have a fairly unique program in terms of how much content we have that are not the traditional technology-based stuff you typically see.
EXP05	I was presented with the idea of the initial course being offered in business and technical programs, and so out of the shoot, I had to create something that fits a broad audience that I could not specify prerequisite. That was a challenge and the main constraint. It did a couple of things for me. First off, I used that to evaluate all the books and things like that. I also decided to go along with my own spin on the material things that were foundational ideas and helped me grow those things. It certainly took a lot more work than I would have thought in the beginning because I had a text, but the text was not very usable. I actually felt bad that I was not using the text as much as I wanted because things were out of order, and they relied on that, so that was the main challenge. However, it was rewarding to see the students respond to a different treatment of the topic.

(continued)

Table 6 (continued)

Cross-Discipline Examples

Experience	Response
EXP06	One major growth area is to move towards more data analytics and data science because with our interdisciplinary, I mean, there is demand there. However, it also is an area that fits in really nicely with a liberal arts interdisciplinary mission because it is so cross-cutting. I think that is one area we would like to do a little bit more is that I will say, related to cybersecurity, a sort of project I would love to undertake. I just need the bandwidth to do it is. I know prospective students and parents of current students. They are interested in getting something that there is a lot of interest in, in cybersecurity, and seeing how to do that. The downside of doing it as an advising tool is that if you do not happen to get in the room with the student to have the conversation, they may not see it.
EXP09	We know our Criminal Justice Department wants to discuss that with us because we already have we have a computer forensics minor which is more of a digital [focus]. We have a computer forensics minor which is more of a digital forensics-like crime approach to. It obviously bleeds into cybersecurity, and that is three of our courses but not touching the ones I mentioned before and three criminal justice courses. So if we build a cybersecurity minor, CJ will want to talk with us, and it makes sense. They offer a cybercrime course [already].

(continued)

Table 6 (continued)

Cross-Discipline Examples

Experience	Response
EXP10	I have developed an undergraduate digital forensic course at [the nearby university]. Prior to moving to [here], I had that content. I created a lot of content myself because, in my opinion, some of the instructors who were delivering a master's degree over there were not even close to the level that they should be in CJ/cybersecurity-related discipline, but somehow they do that. However, so I had to develop my own course. So I used a lot of content from my digital forensic course. So this is kind of a mix of digital forensics and general computer security concepts including the cryptography or the history of computer security, you know, semantic and encryption, you know, everything about the basic of the history of the computing plus also a little bit of a healthy flavor added with a what you call it, get cloud computing related technologies, how the cloud technology being evolved and how it has been affecting the computer security related disciplines. So I had at least two labs created based on cloud computing using the not very advanced lab labs. However, they are getting used to cloud computing, setting up a basic UNIX computer over the cloud print service provider, and doing basic experiments.

(continued)

Table 6 (continued)

Cross-Discipline Examples

Experience	Response
EXP10	Most of the individuals ended up taking that because we have many students who are thinking about a data analytics minor. So if you are thinking about a data analytics minor and we have quite a number of students taking a major in data analytics and a major in accounting because our business majors are also in the same building. Therefore there are plenty of business majors, accounting majors, and math majors who ended up taking either double majors or a minor. So, therefore, almost everybody takes our intro course.

Note: Minor editing for readability

Theme 3 – Curriculum Development*

As the primary aim of this project was to examine the adoption of cybersecurity into liberal arts computing programs, it should be of little surprise that the theme of curriculum development was by far the most dominant code throughout all the transcripts and also denoted with an asterisk. Coding of the theme of curricular development took place 79 times.

EXP04 spoke about giving up some favorite courses and topics, but it was essential to recognize that there was a greater good to achieve from any curriculum. Presented as both a challenge and an opportunity regarding faculty flexibility in what they were willing to teach. EXP04 further expanded on this thought by pointing out that if research and teaching are of interest to a faculty member, then the developed curriculum should strive to bring those topics together. That sentiment related to the later theme of resource constraints. However, EXP04 felt it was significant to put the concept as a positive and not a negative.

EXP06 spent time connecting curriculum development with the theme of ethics and philosophy. When asked about the inclusion of cybersecurity, they stated, "I think information security was a bit like ethics and professional practice. Some of it should be in courses across your curriculum.” This broad, though not deep, the inclusion of security was a common desire, if not an explicit theme. Very few programs had explicit cybersecurity courses but attempted to emphasize the inclusion of concepts within their computing programs.

Due to the theme's nature and the project's cornerstone, it was captured in many other themes, made notable appearances across the literature, and was well-rooted in the themes and theoretical framework. Consideration for breaking the theme into more minor themes was a part of the cyclical reviews. However, the broad nature of the responses lent to the inclusion of the single all-encompassing theme instead of smaller, more specific attempts at coding and themes.

Finally, this theme's most significant potential complication was the nature of the researcher's work in the liberal arts computing curriculum. A few participants were aware of the 2022 SIGCSE article covering curricular innovations in a computer science and liberal arts context and the in-preparation manuscript addressing the CS2023 curricular guidance (Teresco et al., 2022; see also Barnard et al., 2022). The instances where participants acknowledged this during an interview did exist. Journalling allowed for a close review of the transcripts and confirmed that no revisions were needed to prevent the introduction of unconscious bias. However, it either had no impact on the discussion or allowed the further exploration participant's experience using that as a context.

Table 7

Curriculum Development Examples

Experience	Response
EXP02	The NIST security framework was a big one. We felt it was really important. Even back in 2016, at that point, the framework was only a couple of years old, but we kind of recognized pretty quickly that this thing really does an exceptional job describing how organizations can improve this, like a security profile. And so we latched onto that pretty quickly. We had some conversations with the industry. They also, while some were not familiar with the cybersecurity framework, when we talked to them once, they looked at it and said yeah, this is really good. We might switch our processes and procedures over to this at some point. So it was that, and then the faculty member we hired came from the industry to teach many of the cyber courses. And so as you know, in industry, there are quite a few certifications for cybersecurity, and so he kind of, I thought about what our curriculum might look like from a certification perspective, so again we are not the courses, or the curriculum is not really geared towards preparing students for any particular certification.

(continued)

Table 7 (Continued)

Curriculum Development Examples

Experience	Response
EXP02	Nevertheless, recognizing that those certifications exist, like our network security course, covers really a lot of the same topics that you might see in one of those types of certs that the industry promotes fairly heavily. and there is sort of an alphabet soup of certifications, and I am not familiar with all of them. There was a conscious effort to address some of the criteria that those certifications have in terms of what topics we want to emphasize in particular courses. Then the third factor in our curriculum design is conversations with industry, asking what you need your people to do. How are you interested in hiring someone that's incredibly focused on this one area? Do you want people that are more broadly understanding the challenges and issues? Where do you sit in that sort of assessment of skills and knowledge, and how does it fit into what your company does? And so those are really the three main factors we used in developing the curriculum.

(continued)

Table 7 (Continued)

Curriculum Development Examples

Experience	Response
EXP02	We have what is called the core curriculum. What other schools might call general education requirements, however, is called the core here. In the core, there is this one requirement called interdisciplinary studies. Every student has to take one course that satisfies the interdisciplinary studies requirement in the core. So we have a course called cyber Security for Future Presidents, and that is an IDS Course and interdisciplinary studies course. We were teaching roughly once every two years just because of faculty teaching loads and whatnot. However, I think the person we hired teaches most of the cyber courses. They are teaching that cybersecurity for future Presidents for the first time this spring. They are absolutely enjoying the dialogue and the conversations with all of these non-majors. So they asked me if we could teach this every spring instead of once every two years. And so we are currently kind of talking about the impact of that.

(continued)

Table 7 (continued)

Curriculum Development Examples

Experience	Response
EXP03	I mean, I would never, even when I was chair, I would never have made a choice about what to do without consulting the other faculty. And it was only four of us. And any change would go to all four faculty members in the department.
EXP04	We had to give up some of our favorites, and I do not know if there were to sacrifice. We must recognize that there is a greater good that we have to achieve, which is probably one of them of any curriculum. But it is that you cannot feel, you know, you cannot play favorites. You have to focus on what you should be doing for your students and your institution and then make sure that you get that done.
EXP05	There was 2017, there was a cybersecurity curriculum that came out of ACM/IEEE, and I did rely on that to the extent that I could because, I found it fairly challenging in that curriculum and then also even the new rewrite, you know, they really define security in light of kind of the curriculum from larger universities.

(continued)

Table 7 (continued)

Curriculum Development Examples

Experience	Response
EXP05	They will have a lot of prerequisites, like a networking prerequisite, operating system prerequisite, and application coding prerequisite, and it is not easy to map to that in [my institution] because they try to limit the amount of kind of co-requisite sorts of things to give people more flexibility in designing their own curriculum. And we could not enforce, I asked, and they said well, we kind of do that, but we really cannot, especially when we bring in business students. There is no requirement for programming for that.
EXP06	I have thought that if I were going to pull this in is, I probably would not create an actual academic program in cybersecurity. One reason I am not sure I want to do that is that our admissions office has said we want you to have a program in cybersecurity. What I have said is you really don't because the students are going to bring in are the students who are not going to be happy here because they are going to want network management and database management and penetration testing, and they are going to want a curriculum of 25 tech classes and not the liberal arts. Because the students who react to that name tend to want that side of things, which is not what we are trying to do as much. And the students who react positively to us, I think, tend to fall more under the information security umbrella than maybe cybersecurity like that is a bit of a nuanced distinction.

(continued)

Table 7 (continued)

Curriculum Development Examples

Experience	Response
EXP07	I think everybody here is pretty in alignment. That it is the answer is both. We should have more security and privacy security. I think the standalone class topics are also something we ideally touch on from day one to every class. Yeah, and I think the other part of this is also that the ethics get mixed in a lot. Right? Privacy, security, and ethics are sort of the three topics that we say we should have classes that address, and we should also have they should also be addressed as a running theme throughout all of our classes. Accessibility is another theme that is coming up more and more as something we should have a comprehensive line of in our curriculum.
EXP09	We pay attention to ACM/IEEE curriculum every time it comes out. It is not a hard and fast follow just for staffing reasons. But it is definitely a guideline, and we pay attention. So when the last one came out, we added data structures to our information technology curriculum because that last version was like more programming. It is like, okay, here we go. So that is definitely in the mindset. I do not think it is not something we can match item for item I do not think.

(continued)

Table 7 (continued)

Curriculum Development Examples

Experience	Response
EXP11	However, the fact that the curriculum committees are primarily driven by people for whom cybersecurity is equivalent to computer programming. It is extremely taxing. So, it often involves a lot of back and forth where we propose something they send back after months. We have to re-justify it and then re-propose it in a different light. So it becomes a significant burden. I mean, we are still going to do it, of course, but the fact that our colleagues do not have. They do not beg a little bit to understand what they are evaluating. That is a bit of an issue in terms of curriculum for us. That is why we have to develop something that was clear enough so that we could not, we would not stray in terms of curriculum and degree requirements, but we could do whatever we want within the courses, so we do not have to go through the process every single time whenever technology changes or whenever we have to do.

Note: Minor editing for readability

Theme 4 – Ethics and Philosophy

Ethics and philosophy were grouped in a single code and theme, though ethics was the more explicit. Often implied in conjunction with the discussion on ethics was philosophy. Another critical factor was the implicit philosophy discussions centered on the liberal arts versus computing disciplines. A total of 13 times, the theme emerged. As such, it was a secondary theme of some significance

When it came to ethics, though, EXP07 did note that they have a course on security ethics, which was only about three years old. That combination demonstrated the integration of ethics in a specific computing context. That course was of note, as not many liberal arts housed computing-specific ethics courses, much fewer focusing specifically on cybersecurity concepts and implications. It was an exciting combination of cross-discipline, curriculum design, ethics, and philosophy, and it also hinted at the mission and values theme.

The theme was also well supported in the literature as an emerging topic within the field of computer science education. While ethics had long been a traditional part of liberal arts education, utilizing the lens of computing was not widely implemented but was a recurring theme with the participants.

Table 8

Ethics and Philosophy Examples

Experience	Response
EXP03	So yes, we do a whole bunch of that, and then we do ethics in a number of different places. So we call it social, legal, and ethical issues. And that is something that shows up in six or seven different courses where we start to again pull on it in ways that are connected to that particular course topic, right? Rather than offering a course on computing ethics, we basically talk a little bit about it here and a little bit about it there, and in the ai class, you talk about it. In the database class, you talk about privacy, and just so you know, it depends on whatever classes you are in.
EXP04	Five to ten years ago, we did not have any devoted courses and security or ethics, and we intentionally made it a thread. So ethics was a thread in all of our computing courses, and security was a thread at all. And in all of our courses and they did not continue that way. We were very intentional about trying to have some element of every course in computing. A student thinks about security and thinks about ethics somehow.

(continued)

Table 8 (Continued)

Ethics and Philosophy Examples

Experience	Response
EXP04	However, then we realized that to do our students justice. We needed to add courses in cybersecurity, and so not only did we add two courses in security, but we took two courses in networking and one in end-user support. And then we have a nice group of courses that are focused on that security so we can offer in our major that emphasis we can offer a mind, we can offer that endorsement in information technology and security. We still have the thread on ethics, but we decided to offer a specific course in computing ethics.
EXP07	So our chair works in privacy and security. Their research focuses more on the like social impact aspects of it. The class they offer like ethics and privacy in a digital world, this kind of thing. Students read a lot of papers and write papers and do presentations and that kind of thing. We are not doing a lot of coding. We have more technically oriented security classes at [parent university], like hacking for defense is one where they do projects with DARPA, which is really good. Ah, there is something about like byte code analysis or something reverse malware, and so we have more of the, you know, and unfortunately, it does sort of perpetuating the narrative of [my university] being, I guess, less technical.

Note: Minor editing for readability

Theme 5 – Flexibility*

Flexibility was coded 21 times and was a significant theme throughout the project, also denoted with an asterisk. The most prevalent understanding of flexibility was that it pertained to program flexibility. That flexibility meant to the participants having their program and program content fit the institution, the available resources, and the expertise of the faculty in the program.

EXP04 eloquently said, "you have to find a way that you take different things that you want to do and bring them together so that you can do something." The essence of what they were driving at was that in smaller institutions with more limited resources and liberal arts-focused programs, it might not be possible to include every potential discipline as a defined course or program. However, that does not mean teaching a topic like cybersecurity in some fashion within a program was not likely. That requires flexibility in instructor approach and program curricular content.

Another widespread demonstration of program flexibility was the mechanism of a special topics course. Most institutions have some methodology for the quick introduction of a new course to try it out, whatever the reasoning was, and do not go through the normal curricular approval process unless it becomes a regular course. EXP05 mentioned it as a way to provide them with much autonomy to provide cybersecurity content without significant revisions to the overall program. EXP05 was a bit of an outlier because they had been a security professional for a significant number of years before teaching the security classes for their institution

The mechanism of special topics courses was demonstrated in the literature primarily through discourse on cross-discipline course attempts and suggestions of implementation methodology. The flexibility introduced by such a process allowed institutions to take advantage of short-term instructor availability, testing emerging topics, or trial running courses before submission through a whole curriculum revision process. Most institutions had a running a course twice limit before needing to pass through the regular curriculum approval process. In some cases, this was more of an unofficial guideline than anything codified at the institutional level.

Table 9

Flexibility Examples

Experience	Response
EXP02	Yeah, I think it will have to change if we want to keep up with stuff. So I think the technology-based concentration, right? As I mentioned earlier, for each concentration, they are required to take six courses that are in that concentration, and so on. We only have six courses in the technology-based concentration, so they have no choice if they are in that concentration. I suspect, at some point, we will identify some emerging topics or subject areas that we feel we need to cover. And so then the question is, can we cover those emerging topics within the current structure of these six courses, or do we need the seventh course, which means students in this concentration now have some decisions to make, Right? And so, I suspect we will probably add a seventh or maybe even an eighth course in that one concentration that gives students more flexibility and choice.

(continued)

Table 9 (continued)

Flexibility Examples

Experience	Response
EXP04	I loved it for a long time. I taught architecture, I taught operating systems, and I taught an AI class. All of those are gone now because it was more important to move along with what students needed and what the industry needed and what the college might, and so our own favorites, we had to kind of put aside and say no, I have got to really focus on what is going to be best for students in terms of what they are going to learn and a lot of that when in our curriculum, we have what we want to achieve.
EXP04	Flexibility is definitely [needed] when you are a small faculty. We tell our students you have got to be open to learning new things as it happens all the time. You know, we are forced to learn new things all the time to write and then teach them and sometimes like, oh, I am excited to do this other times, like, oh my God, I do not even want to do this one, right? And frankly, there is a time, and it is like, I would rather not teach that, but it is still best for the students. I am going to do everything I can to give them the best experience possible. You have got to be adaptable. You have got to be flexible. You have to keep your eyes on the prize. And the price here is providing the best education for your students, not just on a particular technology, but on a package of skills and abilities that will carry them through decades of experience in the field where you have no idea which direction it is going to go.

(continued)

Table 9 (continued)

Flexibility Examples

Experience	Response
EXP07	We have a lot of flexibility in designing and choosing the classes that we teach as our department because our core is already covered. Okay, there is a sort of perennial question of, do we want to wade into offering our own versions of the core right now? We are following on the side of. We do not want to do that because we like having that flexibility, and, you know, the [parent university] core is good in many ways. And they are iterating on it.
EXP08	Yeah. So we would be delighted to hire someone who would teach cybersecurity, but that is not a must-have and is hard to find. When we started to talk about creating these new positions a couple of years ago, I explained to our development office that we cannot do much as we would like to have a data scientist or a security specialist. We cannot advertise positions specifically in those areas because it could take five years or more to fill them.
EXP10	So, they got me hired, asking me to create my own course that I created. It is more like a general introduction to computer security course, not purely on cybersecurity but general computer security. I was given all the privilege to do it in whatever way that I wanted to do it. I am more toward cyber security and digital forensic background. So, I included those modules too. So we have one general course that we offered at least once every year but did not offer it over the last year because one of the faculty members left at the beginning of last year.

(continued)

Table 9 (continued)

Flexibility Examples

Experience	Response
EXP11	We have limited curricular flexibility unless we are talking about the general degree. Nevertheless, we do have significant atomic autonomy in terms of the courses.

Note: Minor editing for readability

Theme 6 – Mission and Values

The mission and values as a combined theme of programs were one of the more abstract themes to emerge. However, coded 15 times, it emerged as a solid secondary theme. EXP02 talked about the program needing to fit with the college's mission and whether it contributed to the student's holistic development by considering specific content.

The mission and values theme put an interesting angle on the curriculum development theme. What emerged here was that when considering the composition of a program in a liberal arts institution, it needed to be rooted in the institution's mission and values first instead of utilizing particular guidance, certification, or another sort of baseline. That observation was significant in that one of the initially envisioned outcomes of this project was to establish what baselines liberal arts institutions utilized for computing programs. The theme changes that weight to a secondary issue by ensuring that the first look was at the institution before looking at various content guidelines. Both existing and future literature supported this as an essential theme when developing curricula.

Table 10

Mission and Values Examples

Experience	Response
EXP01	So knowledge, it is something that, when you acquire, nobody can take from you.
EXP02	Whereas adjuncts, I do not know about your institution, but we pay adjuncts next to nothing here. And so, where is their motivation for putting in the extra effort to help students? It is, and I do not blame the adjuncts right there getting paid really less than minimum wage when you break down the hours of effort they have to put into a course. And so, I keep on talking to our administration about, and you want faculty that are really committed to doing a good job, and to me, adjuncts in these technical disciplines, they are not going to be committed because they are just not getting paid much. So we do not use objects all that much.
EXP03	We added a couple, of course, is the sophomore level to focus on open source software development and skill, practical skill development. But with the notion that these are skills, experiences, and capabilities that students need to fulfill our institutional mission of a useful education for the common good. So as a computer scientist, what do I need in order to be able to go do something good for the world now? And so you need skills, you know, system administration skills, you need good command-line skills, you need version control, you need to know how to interact with the developer community, you need to know how to use at this point how to interact with software and open source project.

(continued)

Table 10 (Continued)

Mission and Values Examples

Experience	Response
EXP03	These are great opportunities for finding things that people care about that are being launched for the good of society. And so we have integrated a lot of that in our sophomore level, which pulls on those institutional mission themes and gives them these really good practical hands-on skills that employers want simultaneously.
EXP04	That is where that underlying liberal arts is so valuable, is that you are focusing on that underlying lifelong learning, effective communication, focus on your own professional development, focus on those types of things. And then, what are you going to teach them? Well, what is, we can best guess what will be useful, but we know it will change, right? And they need to understand that, and we got to give them that education.
EXP04	You have got to find a way to take different things you want to do and bring them together to do something. Right? So, it is kind of like, if you want to do research and teaching in our institution, you got to bring them together, right? And that is true with liberal arts and smaller institutions: when you have these things that interest you, you have got to find a way to connect them together so that they work.

(continued)

Table 10 (continued)

Mission and Values Examples

Experience	Response
EXP06	So the basis for that as being our capstone is really departmental. I mean, the college is supportive of project-based learning and service learning. But for my department, we follow one of the advantages of having a small department. There are only four of us right now. We were actually pretty unified around pedagogy. All use active learning. I would even go so far as to say we are all constructivists, with most of us specifically falling in the problem-based learning corner of constructivism. So we are the kind of department where we can actually tease out like what kind of constructivist are you and can get into arguments about project-based learning versus problem-based learning and all of those things.
EXP12	And you see that when you talk to different undergraduate institutions, some say very clearly that their goal, their mission is to serve the industries in their area. That used to be very much a junior college perspective, but you see it also now in a fair number of four-year programs. That is what many students want. They see a four-year degree as a mechanism to get a good job. So it is all about getting whatever credentials are needed in order to get that job and improve your economic stature. You know, here a college which is now a four-year school. They do not have a computer science degree, but they do have a computer science emphasis within a business degree.

Note: Minor editing for readability

Theme 7 – Recruitment and Retention

Recruitment and retention was a minor combined theme, coded only a total of five times. Almost the entirety of the time when the topic came up, it was about the recruitment and retention of students into programs. Often this theme was in conjunction with the themes of curriculum development and cross-discipline initiatives.

EXP06 conveyed that liberal arts programs were well-positioned to be cross-disciplinary and that the expansion of interdisciplinary programs had increased computing majors and diversity in programs. The theme seemed to have been less prevalent as participants assumed that they were always trying to bring more or new students into their programs, so often was not made as explicit except when combined with other themes

Table 11

Recruitment and Retention Examples

Experience	Response
EXP06	We have enrollment pressures as our biggest issue, so as I mentioned, we are hiring to grow. Our one major growth area is to move towards more data analytics and data science because with our interdisciplinary, I mean, there is demand there. However, it also is an area that fits in really nicely with a liberal arts interdisciplinary mission because it is so cross-cutting. I think that is one area we would like to do a little bit more is that I will say, related to cybersecurity, a sort of project I would love to undertake. I just need the bandwidth to do it is. I do know that prospective students, parents current students are interested in getting something that there is a lot of interest in, in cybersecurity and seeing how to do that.
EXP06	Yeah, it is something that I think that the process we use now works well for students who kind of realize as they are being CS majors, that security, maybe a career path they are interested in, and then we help work with them.

Note: Minor editing for readability

Theme 8 – Resources

The theme on resources was coded 15 times as a solid secondary theme. Resources were a significant theme but coded less due to the implied nature of the program and the institute type that was the project's focus. The experiences described by the participants were at liberal arts institutions. They presumed foreknowledge that these types of institutions were smaller and had more limited resources.

The usage of adjunct faculty was of note when exploring this theme. EXP06 described their institutions' usage of adjunct faculty but was unique amongst the participants. In almost all instances, adjunct instructors were alumni of their program. Of the other institutions, there was often an avoidance of utilizing contingent faculty. The reasons for this are related to the mission and values of an institution. Participants expressed concerns about the utilization because adjuncts would not be as invested in a particular institution. The ability and experience conveyed with the successful utilization of adjuncts in teaching courses on cybersecurity were fascinating but unique. EXP12 stated they would never utilize instructors or online sources unaffiliated with their institution because "we do not form any connection. The reason why students come here is that they want personal interaction with regular faculty."

Table 12

Resources Examples

Experience	Response
EXP03	We just got really lucky, and it is opportunistic, so we were not looking at that point necessarily to teach anything cyber or to make it, you know, an emphasis in any way the opportunity was too good to pass up, and it is an important topic area, and we knew that so it was a great opportunity for the college to sort of do this. So we did if [the current instructor] went away, what would we do? Yes, honestly, most likely, we would not teach it, at least at the moment with current staffing and current expertise of what we need to offer and what we know and what would be challenging and feasible, Which would be a shame it would be a whole, but you have got to deal with with with what you are capable of doing.

(continued)

Table 12 (Continued)

Resources Examples

Experience	Response
EXP06	I think all of our adjuncts we have used except one over the years have been an alum of our program who had gone out, got a master's degree, and then basically, you know, has come back and talked with us. They are people working in full-time industry jobs whom we can bring back in where we know they know our curriculum. We know they know our pedagogy. It is being able to tell students like this is somebody who is teaching a course in what they do, so that you are getting and we do a lot of mentoring of them and a lot of work with them
EXP08	The big thing I would say is that we have a limited capacity to supervise independent studies, so I want to see those proposals from students who are determined to study something not represented in our regular curriculum. I do not want to see independent study requests from students who are just not excited by the elective offerings and propose something different and or dropped other classes that make up credits, and I would guess as far as teaching load goes, those do not count, no independent. We get to write them on our annual faculty activity reports, but they do not reduce our teaching regular off-course offerings.
EXP09	We cannot add everything. We cannot offer everything. And so that has, I think, really been our curricular driver ever since.

Note: Minor editing for readability

Theme 9 – Semantics and Terminology

Semantics and terminology were a minor theme at only being coded eight times. However, it was also the most surprising in its significance and impact on the general project of cybersecurity and liberal arts computing programs. The surprising aspect was that it often came down to how something the terminology utilized or the name of the course, even if it was essentially the same thing. For example, EXP09 discussed how they changed the name of their network security course to cybersecurity. The course was the same, but it was a more recognizable term for potential students.

However, conversely, EXP07 stated that there would "never be a cybersecurity program" at their institution. The reasoning was that cyber would give other faculty an overly career-preparatory impression. As such, they had privacy and security-related courses but did not explicitly entitle them to cybersecurity.

The integration of writing was another unexpected theme that emerged in the transcripts. In total, the code emerged 11 times. Several participants in the project spoke about how writing had been adopted into their programs as a required element and had become a critical element of a holistically developed student. EXP03 reviewed their college writing program that included discipline-specific writing. The intended inclusion of discipline-specific writing created a more attractive and inspirational approach for the students as they would write in the style of likely later work. For example, the technical documentation better engaged the students with examples described as how-to guides or other field-orientated writing types instead of a research paper in an unrelated discipline.

Table 13

Semantics and Terminology Examples

Experience	Response
EXP02	Maybe this *conversational CS* is the new buzzword. However, the buzzword used to be CS4All and whenever SIGCSE or anybody would promote CS4All, what they really talked about was that everybody should learn how to program. And so here we are as computer science academics, and we are explaining that CS for all means learning how to program. And so we kind of do it to ourselves because we pigeonhole ourselves and say, oh, we think everybody should learn how to program. And we are calling that CS for all, wait a minute here, if we really want to do CS for all, we really should not be focusing just on programming skills, right? We should be talking about the limitations of computing. We should be talking about some of these fundamental things that are real. I think very important. Absolutely and yet get missed somehow in the conversation.

(continued)

Table 13 (Continued)

Semantics and Terminology Examples

Experience	Response
EXP11	So we have to do a significant amount of defending our own discipline internally because everybody wants to jump on the cybersecurity bandwagon or technology bandwagon. We even showed them there was a very nice diagram about it. I am sure you have run into it where there is cybersecurity. Then there is a very, very small bubble that's cyber forensics on the bottom right corner, and then everything else is other concepts. So that was instrumental to making our administration understand. However, the fact that the curriculum committees are primarily driven by people for whom cybersecurity is equivalent to computer programming. It is extremely taxing. So, it often involves a lot of back and forth where we propose something they send back after months. We have to re-justify it and then re-propose it in a different light. So it becomes a significant burden.
EXP12	Well, actually, you could argue that we are not growing up in that we have not identified an underlying core. And what folks are saying is you better specialize at the Bachelor's degree level and not cover the core at the Bachelor's degree and then specialize at the master's and Ph.D. level.

Note: Minor editing for readability

Theme 10 – Writing

The integration of writing was another unexpected theme that emerged in the transcripts. In total, the code emerged 11 times. Several participants in the project spoke about how writing had been adopted into their programs as a required element and had become a critical element of a holistically developed student. EXP03 reviewed their college writing program that included discipline-specific writing. The intended inclusion of discipline-specific writing creates a more attractive and inspirational approach for the students as they would be writing in the style of likely later work. For example, the technical documentation better engages the students with examples described as how-to guides or other field-orientated writing types instead of a research paper in an unrelated discipline.

EXP12 conveyed a similar success in integrating writing into their curriculum as a valuable skill to augment the field's technical skills and academic knowledge. Oddly, the writing topic was the one theme that both those who opposed the perception of being career preparatory orientated and those fine with it found agreement. Whether preparing a student for graduate school or, as EXP03 stated, most of their students did not go to graduate school, making for a more applicable writing style. EXP03 stated they had a capstone thesis as an option for students interested in possible graduate work, so writing was well integrated and found throughout the program.

Table 14

Writing Examples

Experience	Response
EXP03	There is that piece we really dug into the writing across the curriculum, elements of the college, and ethics across the curriculum at the college. We have dug into several things and really sort of jumped in with both feet. We have them deeply integrated into the program.
EXP03	So the college has a three-tier writing program. There is the first-year seminar. There is writing in the discipline, which is intended to happen somewhere in the second and third years. And then there is a capstone piece. And so this writing in the discipline or WID. That piece is traditionally a single course with some writing endemic to your discipline. And so you might imagine that as being a research paper or a tech report or something like that, but we instead took a different approach that we had to put through the curriculum committee and the writing committee and a whole bunch of other places where they are building our students, build a portfolio of writing doing a small amount of writing and a whole bunch of courses. So instead of writing one big research report or one big tech report or whatever, they write a little bit here, and a little bit there and a little bit here and a little bit there, and they have different styles. So in an intro programming class, they write API documentation right there, creating a class. So they wrote the API docs for that and revised them.

(continued)

Table 14 (Continued)

Writing Examples

Experience	Response
EXP03	I think they are thankful they are not writing a 15-page paper with revisions. Most people who go into industry-related jobs are never going to write that kind of paper. For students who are headed for graduate school, we have an honors project option at the senior level where they write a full thesis, so there is a pathway by which they do a ton of that writing if that is the direction they are headed.
EXP12	I will try to keep it short. But so, the idea is what the entire requirements for graduation are. There are a couple of things about min grade points, and there are a few things about the number of practical courses, such as music lessons or PE credits. I will ignore those. But here is the full list. Are you ready? You must take the first-year tutorial. It is a four-credit course, and what you learn is, well, a writing-intensive course. So you must write at least four papers. It is four or five. The number varies because you must have a research experience in terms of the library and that kind of thing. There must be a presentation component, a variety of those kinds of things. And what that does is replace what had previously been freshman writing.

(continued)

Table 14 (continued)

Writing Examples

Experience	Response
EXP12	The issue was in freshman writing. Well, it was taught by the English department. So if you are going to write, you got to write about something you write about, poems, novels, short stories, or whatever. And it was very apparent that an awful lot of students taking that did not give a wit about novels and short stories and poems, and the papers showed that they did not give a whit about that. And then those were turned in, and the English faculty had a grade. That stuff is just a chore. And mostly, it demonstrated that folks did not care. So that is, that was simply wiped out. And the tutorial was going to be a different environment where you would do all sorts of writing and research and presentations and all of that. But it was at least one tutorial offered by every department every year. So you can choose, yes. I am going to have a writing course in computer science. I talked about when I taught the course. The topic I chose was the limits of computing, interactions between technology, ethics and culture, social impact, and all that stuff.

Note: Minor editing for readability

Broader Occurrences and Impressions of Interviews

The most dominant themes were cross-discipline, curriculum development, and flexibility. However, the secondary and minor themes significantly impacted each theme. Minor themes such as semantics and terminology might have been more explicit. However, the project and meeting the same qualifications as the participant pool created a shared understanding of the topic, so the dominant themes were not verbalized as much as possible.

Analyses of Research Questions

The first research question, or RQ1, asked about comparing the growth of the cybersecurity academic discipline and what the lived experience of faculty was with adopting cybersecurity concepts into liberal arts computing programs, and to what degree or rate of integration constituted an innovative program. RQ1 was the project's primary driver, and all themes can be tied back to it directly. The question facilitated the examination of multiple facets of the research question. First, address cybersecurity as a sub-discipline of computing and the level of adoption of relevant concepts into liberal arts computing programs. By answering this, the presumption existed that the project would be able to determine how innovative liberal arts computing programs are with the application of the DOI theory lens. The themes that emerged, precisely that of starting with the missions and values, indicated that quantifying the rate of innovation with the specific element of the frequency of the word cybersecurity was counter-intuitive.

Secondly, and more importantly, by exploring the justifications and reasoning of faculty in liberal arts computing programs, how they design or redesign programs would be addressed to ensure that they provide needed content that achieves desired student outcomes. The themes reinforced that a process was needed to be utilized for developing or redeveloping liberal arts computing programs instead of finding singular curricular guidance, whether or not cybersecurity was the specific computing topic.

The question was a success in that not only did the themes emerge but helped to bring about the most subtle driver behind the curriculum in liberal arts programs. That driver was semantics and terminology. The journal notations refined and defined this as explaining terms and what we do as one of our biggest challenges. While subtle, it was also unexpected in its existence and pervasive nature throughout the literature on computing in the liberal arts and the project. Few liberal arts computing programs defined cybersecurity degrees, though many had at least some form of a security class. That did not mean the content was not present, at least as an embedded concept in other computing courses, but that cybersecurity as a specific focal point in programs was the wrong starting point in evaluating innovation within a liberal arts computing program.

The second research question, or RQ2, asked to compare the growth of cybersecurity as an academic discipline with the lived experience of liberal arts computing program faculty when adopting cybersecurity concepts into liberal arts institutional programs outside of dedicated computing programs as an example of overall innovation and cross-disciplinary education. The primary purpose of asking the question was to establish that cybersecurity can also be considered a life skill. Developing the presumption of cybersecurity as a life skill originated through the literature on newer K-12 and national initiatives. Therefore, the DOI theory lens of the project looked at cybersecurity and whether teaching cybersecurity to all students at a liberal arts institution was an indicator of overall institutional innovation on computing topics. As with RQ1, the themes did not support this as an overall indicator of a measurable rate of innovation.

Through the first revisions of the transcripts, it seemed that the answer to the question was that the topic of cybersecurity outside of liberal arts computing programs did not exist. General education requirements involving cybersecurity were non-existent. However, revisions and reviews demonstrated that cybersecurity was, in some limited instances, made available to students outside of computing programs.

The availability of cybersecurity content to students outside of computing programs in liberal arts institutions emerged through examples of cross-discipline initiatives such as integrating cybersecurity and criminal justice as part of programs. There was an optional cybersecurity course for non-computing majors in one instance, but this was surprising in its rarity. One element of RQ2 that emerged that the project did not address was the nature of any required computing course for all students as part of the general education curriculum. Cybersecurity might be part of an introductory computing course, depending on the responses provided.

Connection to Framework and Primary Lens

According to Peoples (2021), another aspect of the analysis was connecting to the hermeneutic theoretical framework. With *Dasein*, how the researcher being present impacted the project was a primary question. The intersection of the project, meeting the same qualifications for inclusion in the project as the participants, and the often-broad overlapping areas of computing within the programs, impacted the research in various ways. The overlapping nature of roles, while verbally separated from the participants, partially led to understated elements due to a shared understanding of faculty roles and curriculum development. However, this also allowed participants to explore the broader implications of the questions versus the mechanics of their roles.

With *foresight*, or capturing bias and preconceived knowledge about the phenomenon, journaling was a significant methodology in capturing the most significant factors. One of the core assumptions of the project was that there would be a strong desire to include cybersecurity in all programs, that most programs would have cybersecurity content, or create cybersecurity courses for their programs.

With the hermeneutic circle, it was possible to identify the terminology elements and compare those original preconceived notions about cybersecurity in liberal arts computing programs to the experiences of many different faculty at different institutions.

The connection to the lens of DOI was the level of integration of cybersecurity within the program. DOI was the theory that explains how, why, and at what rate innovations grow within particular areas. The most significantly influential themes of cross-discipline, curricular development, and flexibility, the elements of how and why, can be identified and considered by other programs as to what might be applicable in their area.

Rates were defined in five groups as: innovators (first 2.5%), early adopters (next 13.5%), early majorities (next 34%), late majorities (next 34%), and laggards (the final 16%) (Rogers, 1962). The rate turned out to be the most difficult part of the DOI lens to view the project to identify due to the highly variable nature of computing program constructions and the impact of the utilized terms to describe concepts and courses. For example, one institution had adopted cybersecurity concepts into their program and had distinct courses but would not utilize the term to describe the courses themselves.

As stated by EXP12, it often came down to working with resources and figuring out the covered concepts and courses in the available time. Faculty then made conscious decisions on what to include and at what depth. It was surprising, but cybersecurity courses or programs were minimal, new, or non-existent in liberal arts programs that participated in the project. That would place cybersecurity within liberal arts computing programs into the late majorities or laggards categories. Of note was that being in those latter rate categories was not a negative but more reflective of careful consideration of when or how to integrate the subdiscipline of cybersecurity into a more extensive computing program.

Summary

The experiences analyzed achieved the objectives put forth in the research questions. Through the revisionary and cyclical process, transcripts from the interviews were read, reread, and refined based on those multiple coding cycles. A total of ten themes were coded, with some minor themes being more implicit drivers and having a more significant impact on the phenomenon than their frequency alone would suggest. Finally, the themes were related to the research questions and the hermeneutic phenomenological framework and compared to the lens of the diffusion of innovation theory. The core finding was surprising that it was not the specific elements of a liberal arts computing program curriculum that most significantly impacted the decisions of faculty teaching in those programs but that the process of program-level design and student outcomes need to be much broader in consideration. Specific alignment with curriculum guidelines would happen much later. Chapter five contains recommendations on approaching the themes in performing a curricular review to align with planned student outcomes and further research implications.

Chapter Five

Summary, Discussion, and Implications

Introduction

This project developed the findings for adopting cybersecurity curricula into liberal arts computing programs. The themes that emerged were discovered by conducting a hermeneutic phenomenological qualitative research project. The primary data collection mechanism was semi-structured interviews supported by a demographic survey and journaling. The interviews not only explored the current state of cybersecurity within liberal arts programs, but they facilitated exploring the justifications, and more subtle elements of the faculty members lived experience of an undergraduate computing program in a liberal arts institution.

The inspiration for the project also originated from the SIGCSE community and, specifically, the committee on computer science education in liberal arts colleges. While the most variable part of the project, those semi-structured interviews were also the most challenging aspect. The complex nature of professional and research roles created much more variability in interviews and participant pool than initially thought. However, that challenge became a benefit as the project progressed. It allowed richer responses to be probed from the participants to further discussion along a more meaningful line of discussion.

The project coded ten themes through the cyclical coding process, with some minor themes being more implicit drivers and having a more significant impact on the phenomenon than their frequency would have suggested. At the initiation of the project, a few anticipated themes existed. Two of the three most dominant themes fit the expected emerging themes. The anticipated themes that emerged were cross-discipline and curriculum development. Flexibility was a somewhat unexpected theme that emerged. The flexibility theme made sense when contemplated in the context of the other themes. However, it was certainly not anticipated. The other seven themes that came out of the project were not only less expected but subtle, the most significant in what considerations exist when looking at, revising, or otherwise working on curriculum development in a liberal arts computing program.

The combination mentioned earlier of conducting the project and meeting the same qualifications as the selected participants resulted in the more significant themes like mission and values, resources, and semantics and terminology being coded less due to the participants shared understanding of the professional role of the interviewer outside of the doctoral study. However, it was clear that the project was not to incorporate that capacity. Regardless, well, you know, was a phrase uttered by more than one participant during the transcribed experiences. Journaling helped augment and ensure that the meaning of the lived experience was captured correctly and not presumed later, and when those themes emerged in an interview, that shared understanding allowed for a more accurate discussion as time was not needed to establish context.

Review of Themes and Connections to Literature

Theme 1 – Career Preparation

Career Preparation was a theme that emerged not only in the interviews with the participants but also in the literature. The demonstration of the theme emerged in both positive and negative ways. Leebaw (2018) discussed the bias against liberal arts associated with career preparation and emphasized critical thinking. This support for this viewpoint emerged by exploring the lived experience of EXP07 and EXP08 in that cybersecurity has the perception of being overly professionally orientated. The overt introduction of the topic would not go over well with their institution.

However, Tieken (2020) covered that parents sending students to undergraduate institutions viewed liberal arts as enabling many viewpoints and paths of opportunity for students. That optimistic viewpoint was further supported by Teresco et al. (2022) in that many of the efforts in computing programs aim to prepare students for a broad range of careers and their first industry job. The core analysis was that there are relatively extreme viewpoints regarding liberal arts computing programs within liberal arts institutions. The opposing viewpoints were a minority and seemed present as dated viewpoints hanging onto a classical definition of liberal arts and discounting modern technology.

Theme 2 – Cross-Discipline*

Cross-discipline was a significant theme that emerged in both the interviews and the literature. The focus was on integrating computing-related topics with other disciplines and bringing other disciplines into computing-related courses. There was a wide variety of ways this theme emerged, but some presented difficulties in implementing cross-discipline efforts. Walker (2018) noted that the time and effort to create cross-discipline courses did not fit well within typical reward systems for faculty at universities. Roberts et al. (2018) presented that developing a shared vision with the administration and other disciplines could help facilitate cross-discipline efforts.

The theme's most significant observation was the positive aspects and justifications for including cross-discipline initiatives. The CC2020 report was of note as it related the field of computer science to broader topics and specifically mentioned cross-discipline, or CS+X, and how computing has permeated many aspects of society (CC2020 Task Force, 2020). Dekker (2020) continued this positive influence trend by emphasizing that studying only one discipline provides a student with a general perspective, while multiple disciplines facilitate a unique or differing perspective of the field.

A further related trend involved the literature's connection between diversity and inclusion with computing. Brodley et al. (2022) demonstrated that computer science integrated with other disciplines saw increased diversity and inclusion. Payne et al. (2021) further emphasized increased diversity and inclusivity in the context of cybersecurity by showing increased enrollment by integrating cybersecurity with other disciplines.

Teresco et al. (2022) also spent a fair amount of time discussing and demonstrating cross-discipline initiatives. These lived experiences of many of the project's participants in their discussions supported these elements. Criminal Justice came up more than once as an example for bringing in security topics but having a cross-discipline application.

*Theme 3 – Curriculum Development**

As the primary aim of this project was to examine the lived experience of liberal arts computing faculty with implementing cybersecurity in their programs, it was of little surprise that it was a dominant theme. What was initially surprising was the variations in approach to using curricular guidelines. Teresco et al. (2022) summarized many developments in liberal arts computing and described them as varying to a large degree. Worland (1978) discussed models to base the curriculum on, demonstrating that seeking guidance for what to base programs on was not a new theme. The ACM guidelines, notably the CS2013 guidance, were the dominant reference (Joint Task Force on Computing Curricula, 2013).

Walker (2018) covered various ways that new material can be added to a program but did not go as far as recommending a particular set of guidance documents. The emphasis was more on the process of adding and selecting content as opposed to the selection and addition of specific content. Blumenthal (2022b) was of particular note in the connection between interviews and literature. Blumenthal (2022b) looked at ABET accreditation, its coverage of CS2013 guidelines, and further related to liberal arts institutions. Blumenthal (2022b) noted that the increased general education curricula and cross-discipline requirements likely accounted for why so few liberal arts programs were ABET accredited. Teresco et al. (2022) noted the lack of ABET accreditation by liberal arts institutional computing programs.

The curricular development theme allowed for integrating many other themes through the participant's experience. The interviews discussed guidelines that brought forth elements of career preparation, mission and values, and cross-disciplinary efforts, and these were all supported by the literature in some capacity.

Theme 4 – Ethics and Philosophy

Ethics and philosophy was a combined theme that was not as direct in the literature without specific inclusion, but they were subtle themes throughout the interviews. The computing discipline covered ethics as a broad topic, but philosophy emerged in two different frames of reference. First, there were philosophical discussions and elements of literature about the liberal arts as a whole. Secondly, there was literature and discussions on the philosophy of technology as its element. In the literature, the seminal work was by Nielsen (1972) and discussed social responsibility and computing.

The participants presented examples, which the available literature also demonstrated. Burton et al. (2018) presented one notable example of utilizing storytelling with science fiction as a medium for integrating ethics and computer science. Horton et al. (2022) also discussed the integration of ethical issues but presented it as segments within other computer science courses. Segments within other courses seemed to be the more common experience of those who participated in the project. Petelka et al. (2022) stated that the literature on integrating ethics with computing courses does not fully agree on the content or when to teach it. Further support for that viewpoint existed within the variations in the discussion and approach with the participants.

The philosophical elements were more challenging to pin down. However, they were present in the literature and participant experience. Coeckelbergh (2020) was of particular note in covering the philosophy of technology. He noted it had implications for computer science, HCI, and broader society.

Theme 5 – Flexibility*

Flexibility was a theme that, through the interviews, presented multiple facets in the lived experience of the participants. The first aspect of faculty flexibility in teaching what the program requires and not necessarily what the faculty member desires or within that faculty member's previous experience existed only in an abstract fashion within the literature. However, the theme of resources would be the most direct implication of this, so the relevant literature was covered within that theme.

Teresco et al. (2022) covered *flexible pathways* to completing a degree as a trend for liberal arts computing degrees. The reasoning behind this trend involved students coming from a wide variety of backgrounds and so enabling different ways to complete a degree assisted in completing those degrees. Previous work by Fee et al. (2017) introduced this concept and further discussed tracks within computing programs to facilitate flexibility within a major.

The theme of flexibility was otherwise not significantly covered within the literature. So many of the aspects mentioned in the interviews were surprising in their subtlety. Instructor flexibility proved to be of potential interest in future studies.

Theme 6 – Mission and Values

The mission and values was one of the more abstract combined themes. While a solid secondary theme, the most surprising element of the theme was that it emerged as the proper baseline for curricular development. When asked about specific curricular elements such as cybersecurity, the participants tied back to whether it fits the mission and values of their program instead of citing a specific curriculum guideline as their justification for inclusion or exclusion of the topic in their program.

When considering the goal of a liberal arts program as one of producing a graduate who can “think, learn, be creative, and adapt to change,” that holistic approach to program development should not have been as surprising as it was (Detweiler, 2021, p. 31). Many of the other themes emphasized the importance of mission and values, albeit in an indirect fashion. For example, computing programs tied to cross-discipline initiatives via Teresco et al. (2022) and Brodley et al. (2022) demonstrated the combination of computing and other disciplines as increasing diversity and inclusion within those programs. The way participants expressed their lived experience was often as a course or initiative tied back to the goals of the program and the institutional goals.

An indirect mention by Blumenthal (2022b) existed about the impact of the mission and values on liberal arts computing curriculums. Blumenthal (2022b) was explicitly looking at ABET accreditation and noted that many liberal arts programs had differing goals to explain why so few were accredited. However, trying to fit more elements into a program was a concern Walker (2019) expressed when discussing the breadth versus depth of a program. Walker (2019) centered his discussion on an apparent push for programs to be all things to all people while failing to address the impacts on faculty workloads associated with those influences on a program.

Theme 7 – Recruitment and Retention

Recruitment and retention was another combined theme that the participants expressed in recruiting faculty and students into a program. The literature on faculty recruitment in a program was limited and fit better into the theme of resources. Verma (2021) noted that institutions' capacity to train cybersecurity students was a concern for the overall industry. However, Payne et al. (2021) did note that cybersecurity integrated into other disciplines saw increases in enrollment. That demonstrated a compelling justification for cross-disciplinary initiatives combined with diversity efforts and increased enrollment.

Theme 8 – Resources

The theme of resources was a dominant theme of the project. However, the participants emphasized it more subtly due to a presumed shared understanding of the potential constraints placed on computing departments in the liberal arts regarding the number of faculty compared to larger institutions. An important note was that faculty in liberal arts computing programs might be designing or teaching courses such as cybersecurity that are outside of their academic or professional experience. The literature strongly supported that theme from the interviews. D'heedene (1982) discussed this expanded teaching role in their seminal paper on liberal arts computer science programs. Teresco et al. (2022) noted that resource constraints are still a longstanding issue.

Roberts et al. (2018) suggested that one of the causes of faculty not being able to develop more courses such as cross-disciplinary initiatives further was that the faculty are too engaged in daily requirements. The concern of Walker (2019) centered on pushing programs towards the breadth of topics versus deep specialization in specific curriculum areas also relates to the typical expectation that liberal arts computing faculty will develop or teach courses outside of their experience. That concept was further related to the flexibility theme of the faculty.

Theme 9 – Semantics and Terminology

The grouping of semantics and terminology was a minor theme that did not emerge explicitly. However, it was subtle and pervasive throughout the interview process. It was astounding how often participants mentioned how carefully they phrased objectives, course titles, or outcomes regarding their institutions, the computing education community, or other contexts. The impact of some institutions could be significant in their curricular approval process based on how something was titled or described. The same course could be called one title at an institution, while a fundamentally identical course could be titled something entirely different at another institution. However, this theme did not emerge within the literature covered as part of this project, warrants further research, and was a likely candidate for future studies.

Theme 10 – Writing

The integration of writing was another unexpected theme. Several participants in the project spoke about the developed pervasive nature of writing in their programs. The connection with writing was that of being a part of the institution's mission and values and the individual computing program. The theme was not significantly apparent in the literature reviewed for the project but likely exists in a broader context outside literature on computing programs at liberal arts institutions. Reflection on the views expressed by the participants and the inclusion of writing seems logical. The surprising element was a stronger drive to emphasize discipline-specific writing, such as technical guidance, project documentation, and other relevant applications.

Practical Assessment of Project Analysis

The findings firmly demonstrated that qualitative was the correct approach for this project. A quantitative survey would have captured specific elements of the first few themes but not allowed for the expanded range of discoveries. A hermeneutic phenomenological allowed for explicitly incorporating bias and assumptions, revising understanding, and a cyclical approach to developing an understanding of the findings in approaching the lived experiences of the faculty who participated in the project. By exploring those lived experiences, it emerged that a particular curricular guidance document was only applicable if the agreed-upon program's mission and values exist and align with the institutional mission and values. Furthermore, both of those must be in alignment with the desired student outcomes.

At that point, the question was why a program might have an underdeveloped mission and values or agreed upon or why a program may not align with the stated student outcome goals or industry needs. At any institution, turnover happens. The theme of resources identified the faculty as a resource constraint on programs. That constraint could be in the context of the number of faculty, the education or experience of those faculty, or their availability to review new guidelines and enact significant program reviews or revisions. With the context of overloaded faculty working on curricula likely outside of their education or experience, over time, it was not a stretch to see how programs could lose or drift in terms of alignment of their program's mission and values and that association with student outcomes.

The DOI theory as a lens turned out to be more challenging than anticipated. By the nature of the program type, liberal arts programs should be broad-reaching, with a specific discipline as a slight specialization, commonly termed a major. The challenge existed in the presumption that the cybersecurity curriculum would be a specific enough element to gauge the rate of innovation. While it was a specific enough element, the interviews were required to expand into the broader approach of computing programs as not all programs viewed cybersecurity similarly. In the data analysis, it was possible to classify the innovation. The innovation in this project's context was adopting or integrating. The closest the project was able to define the innovation rate within the original context of the DOI lens was in the latter two categories: late majorities and laggards.

Retrospectively, that classification through the lens of the DOI raised the question of whether nor not a standard baseline of cybersecurity curricula in computing degrees at liberal arts institutions was even needed or wanted. The issues with the DOI, when contrasted against the mission and values theme discovered via the phenomenological approach, were more subtle to explain. In that case, it became apparent that the project approached curriculum design from a bottom-up approach looking at a specific sub-discipline of computing. However, the lived experiences captured as part of the project convey that a top-down approach, starting with mission and values, developed a program more aligned with integrating a liberal arts philosophy and defined if tying cybersecurity to student outcomes was a desirable methodology.

The secondary lenses of the TAM theory, and the UTAUT theory, provided helpful insight into this project. With a particular note on UTAUT attempting to explain user intentions with technology and the resultant usage of that technology, that context enhances the understanding of the participants' lived experience. However, the most potent application of the UTAUT would be with students and something to consider for future studies.

Furthermore, the project discovered that different programs could have what turned out to be effectively identical courses, utilizing different course names to fit their program goals. That leads to the core finding about computing programs at liberal arts institutions. Those programs need to address the following three questions first as opposed to trying to select specific curricular content based on a standard that originates from outside of that specific institution:

1) *What differentiates a liberal arts program from a different institutional type if a curriculum is standardized?*
2) *Additionally, if a curriculum is standardized, what differentiates a computing program in a liberal arts institution from a computing program in a different liberal arts institution?*
3) *What parts of a standard or guidance are relevant? Conversely, what parts of a standard are irrelevant to the institution's computing program based on that program's mission and values?*

If standardization was therefore questionable, how are institutions supposed to know what to use or develop when attempting to fulfill student outcomes with the overall computing program? A framework or process for developing a liberal arts computing program is the best approach to address those questions. A process will provide a consistent approach while also preserving the uniqueness of a program and allow a program to keep its institution's mission and values as a foundational element of the program.

While outside the literature review, as the discipline was outside of computing or liberal arts, a fascinating journal article provided a possible reference point for developing such a process. In the journal of chemical education, McGill et al. (2019) identified that the field of chemistry had expanded immensely in its knowledge base over the last few years. As such, there must be a significant consideration as to the undertaken curricular content and pedagogical approaches when developing an undergraduate curriculum. McGill et al. (2019) also tied the reform process to the DOI theory initially proposed by Rogers (1962). While a decent portion of the paper was irrelevant to the discipline of cybersecurity, or computing programs overall, a significant portion of the paper was transferable in that the project provides an application that exists to be a cornerstone for developing a process for curricular planning or revision within liberal arts computing programs.

By their nature, liberal arts institutional programs are supposed to be unique from other institutional types, so a cautious approach to developing identity while utilizing standards. The proposed suggestion is that they should fit the goals and mission of the program. That emphasizes finding mission and values at the top of the top-down program development process. While doing so, the terminology utilized (semantics and terminology – Theme #9) had an outsized impact on the literature and the project itself. Strong consideration and caution should also exist regarding how things are titled and described. Those findings gave us a research-based starting point for the process of program development, redevelopment, or evaluation:

1) *Identify computing programs' mission and values extremely clearly and how that supports the institution's mission and values (Theme #6).*
2) *Review or select curricula that support that mission and values while considering any resource constraints (Theme #8) and being very cognizant of the descriptions used, what usage of titles, and aware that the audience is not only internal to the institution but also external.*

The reasoning for being extremely cognizant of the theme of semantics and terminology was that the stigma of the career preparatory basis of computing programs at liberal arts institutions still exists, no matter how significant the literature or observation supports the high level of computing integration into other disciplines or modern life. Additionally, computing programs also dealt with the stigma of their computing-program counterparts in non-liberal arts institutions as unable to provide an actual computing program. By starting any program changes with identity and walking the terminology line, the program would have that desired differentiator and be true to what works at that particular institution.

Limitations of Project

The project's limitations were rooted in the specific application of utilizing the SIGCSE community. While computer science is the foundational discipline of cybersecurity and typically the foundation of computing programs at liberal arts institutions, there was the potential for programs in liberal arts institutions that have a specific basis in cybersecurity guidelines only and, thereby, would not have been captured in the project findings. The recruitment of participants for the project originated with the SIGCSE listserv and snowball recruitment, so self-selection was present. A few captured demographic factors ensured that self-selection was not overly influential but constituted a limiting factor.

The snowball methodology may have limited variability as well. The snowball methodology was due to some project participants originating from other participants. Thereby there could have been a slight influence on those who were more likely to participate in the project, had been in previous communication with other participants, and could have been of similar dispositions and experiences. That methodology was one of the primary reasons participants were noted by region, accounting for snowball and allowing for recognition of being overly weighted towards one particular characteristic.

In addition to regional impacts, other variables could have further differentiated results, such as race and the sub-types of liberal arts institutions. Future studies could consider other factors. Factors such as the types of liberal arts institutions, faith-based institutions, liberal arts sub-colleges of larger university systems, partner colleges, or other unique variations would merit consideration.

Implications for Future Study

For future study, close consideration is critical when engaging standard or guideline organizations such as the various ACM/IEEE task force groups. Of particular note is the level of engagement. Computing programs in liberal arts institutions need to consider whether they are trying to strictly follow those guidelines or utilize them as inspiration for their programs. If utilizing those guidelines for inspiration, consider whether or not why that could constitute a positive. Future work includes a manuscript in preparation for the upcoming CS2023 aims to provide a process for liberal arts-based computing programs based on any specific curricular guidance (Barnard et al., 2022). That manuscript, submitted for publication, recognized a similar starting point and need for the computing discipline as what was put forth by McGill et al. (2019) for the discipline of chemistry.

A further recommendation would be that future studies compare stated program outcomes with longitudinal student outcomes. Even after a program has been developed or redeveloped, from missions and values through specific curricula elements such as cybersecurity, confirming that students feel their outcome matches their career or academic realities. Can a positive correlation between a liberal arts computing program that follows a standardized review process and an increase in student success or satisfaction levels be an exciting approach? However, it would likely be a very long-term study as it would require the process to be implemented, which could take years, and then students to participate in the study after a set period.

Regarding transferability, the project findings applied to any computing program within a liberal arts institution. As future work requires developing a process or framework for constructing these sorts of programs instead of specific curricular guidance, the transferability was far broader than initially expected. The limiting factor is the specific focal point of the cybersecurity curriculum. An institution that is not liberal arts-based or looking for specific recommendations on what to utilize for the cybersecurity curriculum would only be able to utilize the literature reviewed and not the project findings.

Finally, there were implications in terms of how to integrate ethics and philosophy into computing programs. Liberal arts programs seem well suited to facilitate those topics in a discipline-specific fashion. Additionally, criminal justice emerged several times as a discipline that paired well with computing in liberal arts institutions. The trends in literature and the direction curricular guidance seem to be heading also suggest that social psychology poses merit for modern computing programs based on the liberal arts. A study addressing the why of issues while considering the human element seems to be an exciting combination of the literature, the field of HCI, and psychology that could further facilitate the differentiation of computing programs in liberal arts institutions from their counterparts of different institutional types.

Summary

The project on how cybersecurity had been adopted into liberal arts computing programs successfully discovered that it was a valid question but the wrong place to start in evaluating how faculty have experienced computing programs and whether or not cybersecurity was prevalent within them. Cybersecurity concepts were discovered in most programs, though it was disappointing that there were virtually no general education requirements at any institution the participants had in their lived experience. The themes of cross-discipline, curriculum development and flexibility supported the concept that liberal arts institutions strove to integrate cybersecurity into their programs.

The findings, particularly with the minor themes of mission and values and semantics and terminology, supported the hermeneutic refinement of the original question focusing on the approach to reviewing specific curricular content. Suppose a computing program in a liberal arts institution starts from the basis of wanting the best, most relevant to the institution, program, and specific content, such as cybersecurity. In that last case, it would be far too specific of a level. Instead, programs must operate from a framework of identity, goals, student outcomes and life goals, industry requirements, and content. Once a program completes those elements, only then should a program being reviewed or revised seek out external reference sources. Source such reference or guidance documents such as CSEC2017 were a solid reference point to utilize for a liberal arts computing program and specific curricular content or degree programs such as cybersecurity (Joint Task Force on Cybersecurity Education, 2017; see also Joint Task Force on Computing Curricula, 2013; Raj & Parrish, 2018).

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Appendix A

Consent Form

Project: Exploring the adoption of Cybersecurity in Liberal Arts Computing Programs

Consent Information:

This project explores how Cybersecurity has been included in Liberal Arts Institutional programs. The project will give greater insight into the beneficial elements that Liberal Arts institutions utilize while also providing research-based justifications for current or future program development. This is a research project by Jakob Barnard in conjunction with doctoral studies at the University of the Cumberlands.

You are invited to participate in this research project because of your status as a faculty or curriculum development member at an institution that identifies itself as liberal arts-based and is involved with that institution's computing program or curricula. No compensation is expressed or implied for participating in this survey and interview.

Your participation in this research project is voluntary. You may choose not to participate. You may withdraw anytime if you decide to participate in this research survey. If you decide not to participate in this project or withdraw from participating at any time, you will not be penalized.

The procedure involves filling out an online survey that will take approximately 5 minutes and be only utilized as initial data classification. Your responses will be confidential. Following the initial survey, an interview will be scheduled for approximately 60 minutes. All data is stored in a password-protected electronic format. Personally identifying information such as names of participants or institutions will be replaced with IDs prior to inclusion in the dissertation or any future publications. All classification information will be de-identified and aggregated.

If you have any questions about the research project, please contact Jakob Barnard via email: jbarnard21577@ucumberlands.edu. The dissertation committee chair is Dr. Kathleen Hargiss and can be reached via email: kathleen.hargiss@ucumberlands.edu. This research has been reviewed according to University of the Cumberlands IRB procedures for research involving human subjects, and approval can be found here: https://professorb.info/research-activity/dissertation/.

Appendix B

IRB Approval

UNIVERSITY OF THE CUMBERLANDS

IRB Approval Letter

Principal Investigator: Jakob Barnard
From: Institutional Review Board
Subject: IRB Approved (#901-0122)
Project title: How Cybersecurity has been integrated into Liberal Arts Technology Programs

Approval Date: 01/25/2022

Thank you for submitting your materials to the IRB office. The above referenced human-subjects research project has been approved by the University of the Cumberlands Institutional Review Board. This approval is limited to the approved protocols described in the application which have been reviewed as acceptable activities described by the Office of Human Research Protections (HHS.org).

It has been determined that your study meets federal criteria to qualify as an **expedited study** in accordance with the requirements set forth in 45 CFR 46.110 finding that 1) the research is minimal risk, 2) that if identification of the participants and/or their responses reasonably place them at risk of criminal or civil liability or could be damaging to the participants' financial standing, employability, insurability, or reputation, or be stigmatizing there are reasonable and appropriate protections that will be implemented so that risk related to invasion of privacy and breach of confidentiality are no greater than minimal, and 3) that the research is not classified or does not involve prisoners, with the exception that the expedited review of minor amendments for approved studies involving prisoners may be used.

However, if there are changes to research project in the following areas a modification form must be submitted to the IRB office:

- Substantial change to recruitment materials or consent documents
- Change in the data collection process
- Change in the location of the study
- Change in key personnel
- Change in instrumentation

Principal investigators are responsible for ensuring that studies are conducted according to University protocol. As a principal investigator, you have multiple responsibilities to the IRB, the research subjects and the faculty partner. If you have questions, please feel free to email me at IRB@ucumberlands.edu

Please continue to work with your dissertation advisor as you proceed.

Sincerely,

Jessica H. Nichols

Jessica H. Nichols, PhD
IRB Chair
Graduate School, Director of Research and Ethics University of the Cumberlands

Appendix C

Pre-Interview Questions

1) Are you willing to schedule a full interview? (Presumably via Zoom)

- If not, end the survey

2) Name

3) Email Address

4) Institutional affiliation (Primary)

5) Rank / Title (Adjunct, Instructor, Assistant Professor, or other.)

6) Time in role

7) Faculty, Course Designer, or both?

8) Have you read and agreed to the consent form? *(Form can be found here: https://professorb.info/research-activity/dissertation/)*

**Note, all personally identifying information will be accessible only within the raw data by the PI (Jakob Barnard) and will be replaced with identifiers or aggregated prior to inclusion in the submitted dissertation or any future publications. This pre-interview survey is only for data classification purposes, organization, and setting up of the full interview.*

Appendix D

Interview Questions

1) Can you tell me about your institution and program sizes?

2) What type of Cybersecurity program do you have? (Major, minor, neither)

3) What is the basis of your Cybersecurity curricula or concepts? (ACM/IEEE, ABET, Industry cert, other)

- Probing Question: Is this basis different from an overall program or accreditation?

4) What is/are the Instructors of Record Cybersecurity qualifications? (Masters, Ph.D., certificate, none.)

- Probing Question: Is that qualification in the field of Cybersecurity?

5) Is Cybersecurity taught to general computer science students?

6) Do you feel Cybersecurity should be taught as stand-alone courses or embedded within general computer science courses?

7) Is Cybersecurity taught outside of your computing program?

- Probing Question: Gen ed, FYE, Business Management, etc. Dig into cross-discipline initiatives.

8) How long has the program or Cybersecurity courses been around?

9) Is the program where you want it to be? (Stage of development)

- Probing Question: Why or why not?

10) How do you feel about contracting out new Cybersecurity courses?

- Probing Question: How does prepackaged curriculum relate to your answer?

- Probing Question: If you are an adjunct, do you feel this impacts your work at this institution?
- Probing Question (alternate): Would adjuncts otherwise unaffiliated with your institution be acceptable?

11) What is the process of changing your institution's published curricula (course catalog)?

- Probing Question: How much direct influence do you have on the overall curricula for your institution's programs?
- Probing Question: How long do you feel it takes to implement program revisions from conception to implementation?
- Probing Question: Do you use a process such as "special topics" classes to try out new courses before changing the catalog?

12) Open-ended, but what different experiences or insights might you have with cybersecurity or computing curricula related to this project?

13) Are you aware of anyone else I should contact who might be interested or able to participate in this project?

Appendix E

Site Approvals

Site Permission Approval, Barnard Dissertation Research Study

Amanda Holland-Minkley <ahollandminkley@washjeff.edu>

Mon 1/3/2022 11:05 AM

To: Barnard, Jakob <Jakob.Barnard@uj.edu>

Cc: Braught, Grant <braught@dickinson.edu>

Dear Jakob Barnard:

We have reviewed your request regarding your study and are pleased to support your dissertation research study entitled "How Cybersecurity has been integrated into Liberal Arts Technology Programs." The ACM SIGCSE Committee on Computing Education in Liberal Arts Colleges agrees to collaborate with you for data collection by permitting solicitation of participants from the Committee Listserv or attendees at the Committee's annual Technical Symposium affiliated event. Potential participants will faculty or curriculum development members at institutions that identify themselves as being liberal arts based and are involved with that institutions technology program or curricula development.

This permission covers the time period of January 1st, 2022 to July 1st, 2022. We look forward to supporting your dissertation research. We understand your study requires the approval of the University of the Cumberlands Institutional Review Board and recruitment will not begin until approval is received.

Sincerely,
Amanda Holland-Minkley
Facilitator, ACM SIGCSE Committee on Computing Education in Liberal Arts Colleges
Professor, Computing and Information Studies, Washington & Jefferson College
Email: amh@washjeff.edu
Phone: 724-503-1001 x3400
Address: 60 S. Lincoln St., Washington PA, 15301

Adrienne Decker, SIGCSE Chair
Department of Engineering Education
University at Buffalo
140 Capen Hall
Buffalo, NY 14260

March 25, 2022

University of the Cumberlands IRB
RE: Barnard Research Study

Dear University of Cumberlands IRB:

On behalf of Association of Computing Machinery's Special Interest Group on Computer Science Education (ACM SIGCSE), I am writing to grant permission for Jakob Barnard, a PhD Candidate at University of the Cumberlands, to conduct her/his research titled, "How Cybersecurity has been integrated into Liberal Arts Technology Programs". I understand that Jakob Barnard will recruit from our members subscribed to the SIGCSE-members listserv maintained by ACM via posts to the list and ask them to participate in a one-on-one interview. This permission covers from March 25, 2022 to July 1, 2022.

It is our understanding that this research is being conducted with the oversight of the University of the Cumberlands Institutional Review Board and will comply with any rules and regulations set forth by that oversight body.

Regards,

Adrienne Decker
SIGCSE Chair, 2019-2022