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Digital Badges and E-Portfolios in Cybersecurity Education

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Abstract

The aim of this report is to highlight efforts to develop a digital badging and e-portfolio environment that will illuminate and validate curricular, co-curricular, and extracurricular learning in cybersecurity. This effort includes Cal Poly Pomona and Coastline College, which are both designated as Centers of Academic Excellence in Cyber Defense (CAE-CD) along with a collection of academic and industry partners in creating learning pathways that move interested beginners all the way through to an exciting career in the field of cybersecurity. The pathways are designed to incorporate curricular, co-curricular, and extracurricular learning in a student-managed process in which students consume the learning modules they desire/need, and which move them toward the learning goals they have selected. Students will be able to visualize how formal curricular programs align with their learning journey and plan curricular, co-curricular, and extracurricular learning tasks that fit their plan and allow them to achieve their academic and career goals.

Keywords: Digital badge, skill attainment, e-portfolio, assessment, cybersecurity, education, academic pathways

1. INTRODUCTION

Malcolm Gladwell's prescription of 10,000 hours of practice being required to attain proficiency is an appropriate benchmark for cybersecurity (Manson & Pike, 2014). Reviews of skills required by employers for cybersecurity positions support the notion of students needing extensive training to secure meaningful employment in the field. The mismatch between the skills cybersecurity students can reasonably attain within the classroom and those required by employers demonstrates a need for students to become independent learners and develop additional skills outside of the classroom. Furthermore, Generation Z students are argued to have learning needs and interests that are not, and cannot be, met within current college campuses (Seemiller & Grace, 2017). Generation Z students are also argued to be skeptical of the cost of higher education but are entrepreneurial, innovative, and independent learners (Seemiller & Grace, 2016). The need for extensive skills training and the current inclination of the newest generation of students to be self-directed and entrepreneurial in their learning creates an ideal environment for digital badges and e-portfolios.

Cal Poly Pomona

California State Polytechnic University, Pomona (Cal Poly Pomona) is proud of its longstanding "learn by doing" education philosophy, which provides a competitive advantage for graduates because it extends well beyond students completing hands-on exercises in classrooms. A recently retired professor in Computer Information Systems (CIS) promoted a 50/50 equation meaning that students should ensure that at least 50% of their learning occurs outside of their degree requirements in order to prepare for cybersecurity careers. The CIS program at Cal Poly Pomona promotes competitions, research, internships, and student club activities as venues for students to obtain the "other" 50% of their hands-on learning and skills development. This "other" 50% focuses on competency-based education with students designing, planning, and operating the programs and activities that comprise the learning with support from faculty and university resources.

In the past four years, Cal Poly Pomona has developed the Mitchell C. Hill Student Data Center (SDC) that operates as a hybrid-cloud facility along with a Security Operations Center (SOC) that students operate to monitor the SDC along with studying and researching in the area of cybersecurity operations (Hwang, Pike, & Manson, 2016). There is a companion Malware Analysis Lab (MAL) operated by Computer Science students that focuses on research and learning in the area of computer malware. These facilities are brought together with others under the Cyber Security Instructional Research Project (CSIRP) at Cal Poly Pomona as an extension to the academic programs on campus. The SDC provides computing capabilities for learning modules in courses, competitions, research projects, and more. The SDC also provides cybersecurity learning environments for local middle and high school students.

Initially, students worked as many as 10 hours per week and would invest several hundred hours of work in the SDC and SOC during their time in the program. However, as the program has grown, some students are working as many as 20 hours per week and starting in their 2nd year in the program, thereby amassing thousands of hours of work in the SDC and/or SOC during their time in the program. All of this time devoted to the operations of the SDC and SOC are filled with meaningful learning experiences yet few, if any, are captured in a student's academic transcript.

During the four years the SDC and SOC have been operating, the technical skills required of students within the SDC have continued to rise. After just the first year of the program, students who wanted to start in the SDC or SOC were unable to gain success in activities at either of the facilities as they lacked the needed skills. The SWIFT (Students With an Interest in the Future of Technology) student club came forward to host workshops on topics from Linux, to computer networking, and more, in an effort to prepare students for participation in the SDC and SOC. SWIFT developed an organizational unit called SWIFT Academy that focuses on providing such training.

Student staff from the SDC and SOC then teach additional advanced workshops that build upon the introductory workshops taught by students from SWIFT or other campus clubs. An ecosystem has emerged in which students are teaching workshops that have learning objectives, syllabi, and pedagogies that are subject to a faculty approval process. Students are also running a production hybrid-cloud data center and security operations center. Through these efforts and recognition of the need for practical learning outside the classroom, there is now a defined set of prerequisites between the workshop courses and workshop completion

requirements before Cal Poly Pomona students can start working in the SDC or SOC.

Student-led workshops have already begun to crossover into course curriculum and vice versa. In some cases, faculty will recommend students in their class attend a particular workshop and even offer course assignment credit or extra credit for workshop participation. In other cases, faculty will adopt the content from a workshop and insert it into his or her course as a project or curriculum module. Likewise, student clubs will sometimes take popular technical modules from courses or even corporate training (with permission) and create workshops from that material for students that will not be taking the particular course, or students who need to learn the technical skill before they have taken the course that contains the content.

The process of teaching workshops, operating competitions, and participating in research projects along with the SDC and SOC engages more than 100 students per term in extra-curricular activities to develop hands-on technical skills outside the classroom. Many of these students dedicate hundreds or thousands of hours of time learning and practicing the skills required, which in nearly all cases, are not reflected in any official academic transcripts. More than 1,000 students attended these workshops and programs during the 2018-2019 academic year. Digital badges were determined to be the only tool capable of creating a companion instrument to a student's transcript to document students' skills and activities demonstrated within the curricular, co-curricular, and extracurricular programs at Cal Poly Pomona. E-portfolios were determined to be the appropriate instrument to display pathways created through badges leading students to their desired academic goals as well as being the tool that will allow students to represent their learning journey along with the evidence to demonstrate their skills.

Coastline College

As a 2-year public degree awarding and transfer institution, Coastline College (Coastline) recognizes the value of developing academic pathways for students coming in from the high school and those planning to go on to the 4-year colleges and universities after completing a 2-year degree at Coastline. To draw in students from the local middle schools and high schools, Coastline has developed structured pathways to engage these students with events and activities that include Cybersecurity Pathway Days, CyberTech Girls events, GenCyber summer camps, and cyber defense competitions such as CyberPatriot and Capture-the-Flag. These events are held at Coastline's Garden Grove campus in Southern California to build the relationship between the students, the college, and its faculty members. The activities include training and hands-on workshops that raise awareness about Coastline's cybersecurity program and help students develop their skills and interest in cybersecurity professions.

Hosting these types of events, allows Coastline to expand beyond the traditional outreach strategies hosted at the middle school and high school campuses in which students may talk to faculty at a career fair table without much time for hands-on activities. By hosting the cybersecurity activities at the college campus, Coastline showcases the classroom equipment, learning environment, and hosts learning and awareness activities to help students from the 8th-12th grades to become familiar with and prepared for the college setting.

Coastline is exploring the use of digital badges within its Learning Management System to track student progress and achievements for GenCyber and CyberTech Girls events. Students will be able to earn badges after completing practical exercises and assessments that demonstrate a particular level of skill attainment. In the coming year, Coastline will begin exploring the use of Portfolium to track student program progress and successful industry certification exam attempts to guide students in further development of a robust e-portfolio.

Additionally, Coastline offers dual and concurrent enrollment courses at high school campuses in the Orange County, CA area. The concurrent enrollment courses offered in the Santa Ana Unified School District (SAUSD) are taught by Coastline College faculty and SAUSD students are bussed from multiple high schools to one high school campus for weekly class meetings. This allows the students to earn college credit while in high school and begin developing cybersecurity skills in preparation for cybersecurity roles or for their extracurricular activities at Coastline or Cal Poly Pomona's SDC and/or SOC.

Coastline's dual enrollment with La Quinta High School (LQHS) includes college-credit courses taught during the regular school day, by an LQHS teacher. In addition to the college coursework, many of the students compete in

the CyberPatriot competition hosted at Coastline. The Coastline courses offered at LQHS include Network+, Security+, and Ethical Hacking which will provide students with cybersecurity skills that they can continue to develop as they move to higher education institutions.
Coastline has established agreements with 4-year institutions through the Learning 1st Program, allowing Coastline students to concurrently enroll in both the 2-year degree courses and 4-year degree courses at Coastline and a University. This is sometimes referred to as a 2+2 program in which students receive full transfer credit from the 2-year school to the 4-year school's bachelor's degree program. Students complete 2+2 programs to earn both the associate and bachelor's degree by taking classes at both schools in a major with pre-determined courses.

2. LITERATURE REVIEW

There is a growing body of literature around digital badges revealing optimism regarding the potential impact on skill attainment and advancement. Terms including digital badges, micro-credentials, or even credentials denote web-enabled depictions of an individual's accomplishments or skills (Gibson, Ostashewski, Flintoff, Grant, & Knight, 2015). A first key area of common ground within the literature focuses on the ability of digital badges to reveal learning pathways, making these pathways transparent to learners (Pitt, Bell, Strickman, & Davis, 2019; (Davis & Singh, 2015; Gibson et al., 2015; Pitt et al., 2019). These learning pathways can be a mix of formal curriculum in an academic program along with co-curricular or extracurricular learning activities.

Conversely, the pathways can be completely comprised of extracurricular activities including industry-based learning and badging/certification options. A second key area of common ground within the literature focuses on the ability of digital badges to validate possession of a key skill (Gibson et al., 2015; May, 2016). Examples of skills validation for employees is evident in the literature and trade outlets from industries spanning human resources to AV installation, and education to construction (Berry, Airhart, & Byrd, 2016; "First micro-credential A big step forward for construction," 2018, "Introducing micro-credentials for AV installation," 2017, "NPA introduces parking safety certificate program: Micro-credential program provides parking facility safety and risk reduction tools," 2016; Goerner, 2016; Gorlin, 2018).

Literature varies on the appropriate scope of a digital badge. There is strong support in the literature for a badge reflecting an individual skill or accomplishment (Goerner, 2016; May, 2016). Others; however, add to this by comparing badges today to e-commerce in the latter 1990s with the notion that education providers who ignore badges could begin a steady decline (Hickey, 2017).

E-portfolios have an immense literature base that reflects many uses for this technology. E-portfolios are used in classrooms to assess student learning and in program-level assessment (Wang & Jeffrey, 2017). E-portfolios are also used as digital resumes for students to display evidence of learning to potential employers or higher-level education admissions, or to demonstrate professional development in an individual's workplace.

The review of literature focused on education, nursing, and law. Education was a point of focus as Cal Poly Pomona is deploying e-portfolios in an education setting. Medicine and law were reviewed as they are professional disciplines and have been argued to be appropriate reference disciplines for information systems (Davenport & Markus, 1999). Within medicine, we focused on nursing literature as it has a strong focus on application that matches well with the cybersecurity field.

The first major benefit found for e-portfolios is centered around learners' self-reflection and self-regulated learning (Carl & Strydom, 2017; Chin-Yuan Lai & Cheng-Chih Wu, 2016; Rafeldt et al., 2014). A second major benefit of e-portfolios was found in helping learners to tell a media-rich story related to their learning journey (Haverkamp & Vogt, 2015). Yet another benefit of e-portfolios found in literature is the ability to link theory to practice (Chittum, 2018; Cunningham, Bartesaghi, Bowman, & Bender, 2017). There are many more benefits of e-portfolios that cannot be fit into this paper, however this paper simply reported on the dominant benefits found pertaining to the goal of this paper. Also, there is a large literature base supporting the three benefits of e-portfolios presented here which have been limited to just the few that best supports the purpose of this paper.

3. DIGITAL BADGES & E-PORTFOLIOS

The research study examined digital badges and e-portfolios to enhance and assess co-curricular and extracurricular student activities that support the information systems program at Cal Poly Pomona. The ability to accurately assess co-curricular and extracurricular work is especially important in a polytechnic setting as there is a significant focus on resources and the importance of experiential, hands-on learning activities. This research sought to determine the efficacy of these technologies with respect to serving as a tool to report student-learning outcomes in activities that span formal curriculum as well as co-curricular and extracurricular learning activities. Digital badges are becoming increasingly important as they are a specific measure of skill attainment that can be tied to in-demand technical workplace skills.

Digital badges can also provide evidence of skill achievement in co-curricular and extra-curricular programs between schools. For instance, a student may earn badges in high school that allow them to start in more advanced opportunities at the community college. Badges earned in high school and community college may allow students to start work right away in the SDC or SOC at Cal Poly Pomona without spending the year that is typically required to gain the skills to start working in these facilities. This is especially important for transfer students to ensure they get started immediately in these facilities as they only have two years to complete their bachelor's degrees.

Digital Badges

A digital badge is a shareable credential providing evidence of a learning achievement. Digital badges fall into two categories which are competency and participation badges. A competency badge requires an assessment of skills and measures of achievement. The badge description includes the items that were assessed and the performance outcome that was required to earn the badge. Participation badges indicate that an individual has participated in an event, such as attendance at a workshop or lecture. The competency and participation badges are sometimes offered in tandem where an individual has attended a workshop and then successfully completes skills test at the end to demonstrate learning.

The literature supports three distinct drivers supporting the use of digital badges. The first driver is the potential motivation for students in earning a badge as an extrinsic reward for excellence or even drive engagement by linking students' achievements within a leaderboard and creating a competitive element to learning (Denny, 2013; Gibson et al., 2015). Second is the potential for a digital badging system to help students envision integrated curricular, co-curricular and extracurricular learning paths that prepare them to enter careers (Pitt et al., 2019). The third driver is the potential for digital badges to help students demonstrate the collection of skill attainment to better market their skills, knowledge, and relevant experiences to potential employers. There is support for the notion that companies are seeking ways to gain additional insight into the skills and abilities of applicants and digital badges are a potential solution (Raish & Rimland, 2016). There is also evidence that CIOs are seeking to gain insight into the skills of current employees meaning that digital badges may already be a valued asset within IT organizations before a student applies for employment (May, 2016).

Figure 1 shows a brief example of an overly simplified learning pathway for demonstration purposes. In this case, a student took an advanced placement (AP) Python course while in high school, a Computer Networking course from a community college, and a Linux course from Lynda.com. This group of badges/certifications allowed the student to qualify for the SOC Associate badge at Cal Poly Pomona which is a collection of sub-badges. The student would then be able to immediately begin working in the SOC Associate role in the Security Operations Center at Cal Poly Pomona and begin working on the Splunk certification, which is earned directly from Splunk, and the SOC Operations badge which comes from successfully completing a battery of tasks and 100 hours of work as an analyst in the SOC. A student can progress through this learning pathway without any formal articulation agreements as the SOC (along with the SDC) are extracurricular environments. Of course, proper planning should ensure that the AP Python course taken in high school and the Computer Networking class from the community college each articulated to appropriate courses in the Cal Poly Pomona curriculum. The student would not likely receive academic credit for either the Linux course or Splunk certification, but this would be known in advance allowing the student to plan accordingly.

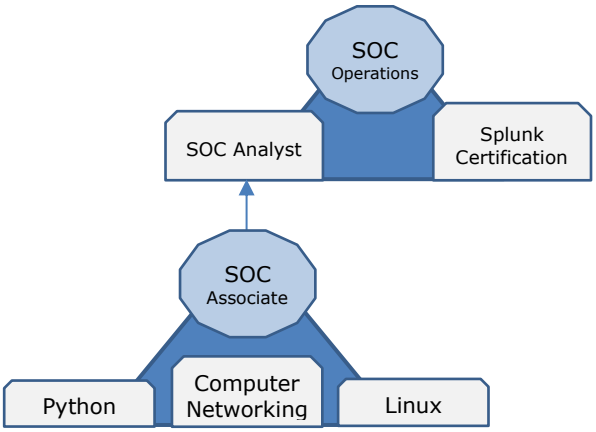

Figure 1 SOC Learning Pathway

More than a dozen employers of cybersecurity students from Cal Poly Pomona have asked for the implementation of digital badging systems. Employers such as IBM and AWS have entered into a joint badging process in which students earn some badges from Cal Poly Pomona and some from these companies while they are in school. Cisco has recently announced a scaling back of their certification programs, to be replaced by the implementation of digital badging. This process of digital badging appears to be growing and it is believed that it will become pervasive over time.

E-Portfolios

As noted in the literature review, there are three distinct drivers for the use of e-portfolios which were learner self-reflection, learner storytelling, and linking theory to practice (Carl & Strydom, 2017; Chin-Yuan Lai & Cheng-Chih Wu, 2016; Chittum, 2018; Cunningham et al., 2017; Haverkamp & Vogt, 2015; Rafeldt et al., 2014). Portfolium has been selected and procured for use in Cal Poly Pomona's e-portfolio and digital badging venture.

E-Portfolios and Digital Badging

At Cal Poly Pomona digital badging and e-portfolios are implemented in Portfolium, a commercial product. Portfolium is a complete solution, providing completely integrated digital badging and e-portfolios. Badges can also be output to professional networking platforms such as LinkedIn and other digital platforms from Portfolium. The benefits derived from e-portfolios and digital badging for Cal Poly's program are shown in Table 1. The integration of e-portfolios and digital badging, and then the subsequent integration of these two technologies to existing systems such as Cal Poly Pomona's Student Information System (SIS) have been reviewed; however, are expected to create a challenge throughout the e-portfolio/badging implementation process.

Table 1 *E-Portfolio and Digital Badging Benefits*

Benefits of E-Portfolio and Digital Badging	
E-Portfolios	Digital Badges
Self-reflection	Extrinsic Motivation
Storytelling	Illuminate learning pathways
Linking theory to practice	Market to employers or higher-level education

Several literature sources speak to e-portfolios supporting learning and evidence of achievement (Trevitt, Macduff, & Steed, 2014). However, in Cal Poly Pomona's environment digital badging are viewed as being the tool that offers evidence of achievement and the e-portfolio as a system to support evidence of learning. Likewise, Cal Poly Pomona is planning to use e-portfolios to support evidence of learning in a mixed environment of curricular, co-curricular, and extracurricular work but this will overlap to at least some extent with the function of the SIS. The process of determining which information is maintained, managed, and assessed in which systems will certainly create lively debate among stakeholders on campus.

4. CHALLENGES OF DIGITAL BADGING AND E-PORTFOLIO USE

There are several badge e-portfolio platforms currently on the market. A quick online search shows over thirty such solutions. However, the premise is on adoption by the e-portfolio systems and professional social media platforms such as LinkedIn as to acceptance. Many platforms and applications can accept badges in their rudimentary state as a bitmap or other digital graphic file. This demonstrates that there is an ambiguity of acceptance currently emerging in this area.

Enter open badge standards. The Mozilla Foundation has developed a technical standard called Open Badges and since the early 2010's they have endeavored to develop a contextual framework for organizations to adopt their standard through a partnership alliance (LaFrate, 2017). This concept has solid

foundations through the professional and academic measurements of rigor for the eventual holder of a certification, certificate, or degree. The general stance in academic and professional development is that digital badges are an evolutionary step for learners to gauge their progress (Stotz, 2017).

A question then comes to the accreditation and broad acceptance of badges within and across organizational lines. In much the same way that one university accepts another's courses for articulation purposes, the focus on digital badges opens up another realm of possibility. This can contribute to the badge accreditation process in the form of compact skill assessments that map up to joined learning objectives that two or more institutions share. The other side of the argument and more challenging aspects are the technical and platform-specific hurdles that can get in the way of accomplishing these agreements.
A possible solution to this would be a generally accepted standard throughout higher education. However, as previously stated, with over thirty badging solutions and limited e-portfolio guidance there is a challenge present in this space for collaboration. Only time and further research on adoption of platforms will show the direction of digital badges and e-portfolios in higher education. as with many types of technological advancements, until either a breakthrough or in this case a more "viral" moment occurs, we as educators will experiment with different methods, platforms, and products all the while sharing our research in the quest to advance this pedagogical and andrological initiatives.

5. OPPORTUNITIES FOR FUTURE RESEARCH

While previous research and the findings of the study provide a promising framework for pathways with supplemental credentialing through digital badging and micro-certificates housed in an e-portfolio repository, there are areas that need additional attention and research to move the framework forward. There is a need to understand the process for establishing, articulating, and updating industry and higher education standards for badging and e-portfolios. Following this idea, is a need to measure the rate or speed of digital badging and e-portfolio adoption by industry and higher education. Finally, once badging and e-portfolio standards are established and fully implemented there needs to be a measure of the impact of digital badging and e-portfolios on rates of graduation, transfer, job attainment, job promotion, and employee retention.

6. CONCLUSION

E-portfolios and digital badging are an exciting option to demonstrate skill achievement outside the classroom, extend cybersecurity learning, and provide or illuminate pathways for learners. Cal Poly Pomona and Coastline College are both designated as Centers of Academic Excellence in Cyber Defense (CAE-CD) and are working with academic and industry partners to make technical skills pathways transparent to learners from middle school all the way into professional careers. This project focuses on empowering learners to understand the challenges and opportunities ahead of them through digital badging and e-portfolios that can be used to show the pathway early on and track achievements along the way, culminating in a more complete display of the learners skills and achievements inside and outside the classroom. It also provides a perspective for the development, implementation, and refinement of a learning journey that includes a broad array of content and potential patterns to consume the content. Cal Poly Pomona and Coastline envision learners ultimately assembling an academic transcript and an e-portfolio with digital badges that summarize the learner's career preparation. This learning journey would then continue as the learner manages career advancement and market shifts in the workplace. Finally, the challenges are explored facing the accreditation and acceptance of digital badges and e-portfolios in academia and industry alike. Further research needs to be conducted to develop badges into established pathways that are widely recognized and accepted.

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