Supporting learners' STEM-oriented career pathways with digital badges

Caroline R. Pitt
University of Washington Information School, Seattle, Washington, USA
Adam Bell
College of Education, University of Washington, Seattle, Washington, USA, and
Rose Strickman and Katie Davis
University of Washington Information School, Seattle, Washington, USA

Received 16 June 2018
Revised 3 October 2018
Accepted 4 October 2018

Abstract

Purpose – This paper aims to investigate the potential for digital badges to support alternate learning and career pathways in formal and informal learning environments. Stakeholder groups in higher education and industry discussed how digital badges might transform current processes of admitting undergraduate students and hiring young professionals.

Design/methodology/approach – This research uses a thematic analysis of in-depth interviews with 30 stakeholders in higher education and the technology industry.

Findings – Interview participants expressed optimism about the potential for digital badges to make learning pathways visible to learners and external audiences and to promote equity in STEM (STEM: science, technology, engineering, and mathematics) education and careers. Participants noted several obstacles, largely focused on issues of credibility and logistics of working with badges across settings.

Research limitations/implications – Though the research approach is limited in geographic scope, the findings have broad applicability and insight for the use of digital badges in general.

Practical implications – Education policymakers, employers and scholars will be able to use the insights from this investigation in their efforts to find innovative ways to expand and diversify the STEM workforce, as well as support a wider range of learners than is currently supported by initiatives aligned with the school-to-workforce pipeline metaphor.

Originality/value – This paper directly confronts issues of real-world applications of digital badges by discussing practical implications with college admissions officers and employers. The current study fills a need for research that investigates the use of digital badges across – as opposed to within – contexts.

Keywords Lifelong learning, STEM education, Informal learning, Digital badges, Media in education, Human-computer interface, Learning pathways

Paper type Research paper

1. Introduction

Despite rising demand, the USA continues to face a shortage of workers skilled in science, technology, engineering and mathematics (STEM) fields (Deming, 2017). At the same time, too many youth experience a disconnect between what they study in school, what genuinely

The authors thank the National Science Foundation for its support of this research under grant *DRL-1452672*. They would also like to thank Ada Kim for her work on this project, as well as the science center staff and students who participated in the research and all interviewees.

Information and Learning Science

2398-5348
DOI 10.1108/ILS-06-2018-0050

interests them and the career opportunities that are open to them upon graduation (Ito *et al.*, 2013). Moreover, a substantial portion of these youth never even get a chance to seek career opportunities because they do not make it to graduation.

Policy initiatives have largely approached this problem from the perspective of the school-to-workforce "pipeline" (Cannady *et al.*, 2014). These initiatives focus attention on preventing "leaks" at certain points along the pipeline. By focusing on a singular path to the STEM workforce, such efforts fail to account for the multiple trajectories that learners may pursue toward a STEM-oriented career (Cannady *et al.*, 2014). As a result, they miss key opportunities to expand and diversify the STEM workforce and increase educational equity.

In the current study, we investigated the perspectives of stakeholders in higher education and the technology industry regarding the potential for digital badges to support multiple trajectories to a STEM career. We ask: *How do college admissions officers and human resource managers perceive the value of digital badges in education? What implications do these perspectives hold with respect to the potential for digital badges to support learners' STEM-oriented career pathways?*

Digital badges – or credentials – are Web-enabled representations of a person's skills and accomplishments (Gibson *et al.*, 2015; Grant, 2016). Their metadata can be used to indicate important information, such as when the badge was earned, what the earner had to do to gain the badge and the institution that issued and/or endorsed the badge. Because digital badges are Web-based, they can be shared across boundaries and contexts to highlight the expertise of the individual who has earned them (Hickey *et al.*, 2015, 2018). These *boundary objects* can help learners communicate their expertise across settings and provide documentation of their experiences (Bowker and Star, 1999; Star and Griesemer, 1989). Previous research has suggested that badges have strong potential in this role, but there is still progress to be made towards their widespread acceptance (Bell and Davis, 2016; Davis and Fullerton, 2016; Klein and Davis, 2016).

We conducted interviews with 30 stakeholders in higher education and the technology industry, including 19 college admissions officers and 11 human resources managers whose portfolios focused on technology-centered positions. We presented interview participants with a prototype of a digital badge system for use in an afterschool high school science program and asked them to reflect on its potential usefulness in their specific professional context.

Our analysis of the interviews revealed an overarching optimism among stakeholders with respect to digital badges' ability to make learning pathways visible to learners and external audiences and to potentially promote equity in STEM education and careers. Stakeholders also identified specific hurdles that would prevent the viability of digital badges. These hurdles, which align with previous research investigating digital badges (Davis and Klein, 2015; Davis and Singh, 2015), included challenges establishing the credibility and value of individual badges and the logistics associated with introducing a new practice of credentialing.

Although prior work has investigated opportunities and challenges associated with using digital badges in learning and employment contexts, still missing is an understanding of the specific situations and contexts in which digital badges could be used to address failures in existing policy initiatives aimed at promoting STEM career pathways. College admissions officers and human resources managers are well positioned to provide this insight due to their role as traditional gatekeepers to learning and career opportunities. The findings from the current study will be useful to policymakers, employers and scholars who are interested in exploring innovative ways to expand and diversify the STEM workforce while, at the same time, supporting a wider range of learners.

2. Related work

2.1 Rethinking the school-to-workforce pipeline

The labor market exerts considerable influence on the way US education is structured, including what is taught in schools and what careers students are encouraged to pursue upon graduation (Cannady *et al.*, 2014). In recent years, growing political and economic pressure for technological innovation has resulted in high demand for jobs in STEM. The US education system has responded to this pressure by placing increased emphasis on STEM-focused curricula (Deming, 2017). Despite this emphasis, the USA currently faces a shortage of workers trained in STEM-related fields.

The school-to-workforce pipeline represents the dominant metaphor guiding policy initiatives aimed at improving STEM education and filling the gap in the STEM workforce (Cannady *et al.*, 2014). The pipeline metaphor posits a singular pathway from STEM education to STEM-oriented employment. "Leaks" at various points along the pipeline account for the current shortage of STEM workers. These leaks are thought to occur at key points in a student's educational trajectory, such as failing to pass algebra by the end of middle school or calculus by the end of high school. The solution posed in this metaphor, therefore, is to plug leaks along this trajectory to ensure that more students meet standard academic benchmarks and graduate from school with the necessary skills to join the STEM workforce. Despite a host of policy initiatives designed to plug the leaky school-to-workforce pipeline, a shortage in STEM workers persists.

Cannady *et al.* (2014) critique the pipeline metaphor for relying too heavily on standard academic benchmarks such as algebra and calculus and failing to take into account factors such as interest, identity, motivation, social context and alternate pathways. The result, they argue, is undue power given to traditional gatekeepers and credentialing systems. They point to research showing that students' interest in and motivation to pursue STEM subjects matter just as much as their academic achievement in these subjects (Tai *et al.*, 2006; Tyson, 2011). In their own analysis of longitudinal data involving eighth graders and their college and job outcomes, Cannady *et al.* showed that many students who met standard academic benchmarks chose not to pursue STEM careers, just as many students who ended up in the STEM workforce arrived there through non-traditional routes.

Cannady *et al.* (2014) call for interventions and policies that emphasize alternate routes to STEM careers. Unlike efforts inspired by the leaky pipeline metaphor, these alternate routes should place less weight on traditional academic benchmarks and gatekeepers and do more to acknowledge and incorporate students' interests, motivations and identities as learners (Holland and Lave, 2009). By acknowledging multiple routes to a STEM career, such an approach promises to be more inclusive of a wider range of students, including those who have traditionally been underrepresented in STEM fields (Spaulding and Johnson, 2016). Indeed, if we do not attend to how young women or marginalized youth (Black and Latinx) are consistently pushed out of STEM studies (Wyn *et al.*, 2017), for example, then the current model of STEM education will continue tracking students (Adamuti-Trache and Andres, 2008) in ways that inhibit innovation based on systemic inequities (Leonhardt, 2017).

Rather than continuing to force learners to conform to the school-to-workforce pipeline, a concerted effort should be made to identify multiple ways for learners to be successful in entering the STEM field. In the current work, we draw on two theoretical approaches that move beyond the school-to-workforce pipeline by considering a plurality of experiences, values and settings associated with learning: *learning ecologies* (Barron, 2006) and *cultural learning pathways* (Bricker and Bell, 2014). We also examine how information behavior theories (Chatman, 1999, 2000; Fisher *et al.*, 2004; Fisher and Naumer, 2006; Savolainen, 2009) can help us understand this plurality of physical and virtual spaces and the

information behaviors present in them, as well as the role of digital badges as boundary objects (Bowker and Star, 1999; Star and Griesemer, 1989) as students move between diverse and distinct settings. These theoretical lenses can help further our understanding of badge ecosystems and how they might be improved in the future.

2.2 From one pipeline to multiple pathways

School learning typically seeks to control the trajectory of students in an attempt to develop expertise within knowledge domains such as STEM learning (Tyson and Roksa, 2016). This control is often exerted through course requirements, standardized testing and other modes of gatekeeping. However, these practices neglect the ecological factors that influence developmental change (Bronfenbrenner, 1979) and the formation of interest-driven expertise (Crowley and Jacobs, 2002; Renninger, 2009). A more holistic approach for understanding an individual's development is a *learning ecology framework* (Barron, 2006). According to Barron (2006), a learning ecology includes an individual's identity, personal interest and out-of-school activities that are established through situated practices with families, local institutions (e.g. museums) and relationships with cultural artifacts such as books or digital media. In essence, understanding a person's learning ecology involves looking across boundaries of space and time to identify multiple avenues for success that are personally defined and culturally situated.

Of course, formal schooling should not be excluded in a student's learning ecology; however, by placing emphasis on personal interest, it becomes clear that informal learning with peers often leads young people to seek learning opportunities in formal educational settings to develop their interests further (Ito *et al.*, 2013). For example, in her study of young people's learning ecologies, Barron (2006) interviewed a Chinese-American, middle school student named Stephanie who had adept computer skills. As early as seventh grade, Stephanie knew that computers would be an important part of her future career. Still, most of Stephanie's computer use was not in school but on a family-shared computer where she participated in Geocities, an online community in which she and her friends developed websites and blogs. Driven by her interest, Stephanie completed almost every technology class offered in her school by the time she entered eighth grade. At this point, with no other institutional supports, Stephanie had to find her own learning opportunities through more extensive online learning communities and through the resources provided by her family. Clearly, Stephanie continued to develop her computer expertise, but there were no formal structures available to recognize and validate this knowledge.

Parallel to learning ecologies, *cultural learning pathways* represent a way to support multiple trajectories of success across boundaries of time, space and cultural difference (Bricker and Bell, 2014). Bricker and Bell articulate the importance of supporting the agency and identity of learners as they seek alternative pathways toward developing their expertise in a domain. To illustrate this process, the researchers documented how a young girl, adopted from Haiti, participated with her mother in perfume mixing experiments. Through these experiences, the girl's mother affirmed her emerging identity as a scientist by providing culturally relevant support that positioned her as a person capable of doing science.

The informal activities in which the young girl participated were not recognized as having any connection to the institutional pipeline that existed within formal education (Bricker and Bell, 2014). As a result, she had no opportunity to leverage her out-of-school science learning and identity to support her in-school science learning. Like the rest of her classmates, she experienced a singular science pathway in school. Had her teachers known about and incorporated her weekend perfume mixing into her school learning experiences,

the girl would have had a chance to pursue a science learning pathway that resonated with her interests, cultural values and sense of identity. In this way, cultural learning pathways make it possible for diverse learners to succeed in STEM learning.

2.3 Insights from information behavior

Information behavior theories can also inform ecological frameworks of learning, providing insight into how communities exchange information within specific contexts or spaces. A more complete understanding of highly contextual information behaviors can allow us to anticipate and address some of the challenges and opportunities that arise in digital badge initiatives, as discussed in previous work and Hickey *et al.* (2015). Cannady *et al.* (2014) stress the importance of social context in their critique of the pipeline metaphor, and these theories of information seeking and sharing focus particularly on this social aspect (Savolainen, 2009). Considering how digital badges work as boundary objects (Bowker and Star, 1999; Star and Griesemer, 1989) across contexts can also further our understanding of their role in complex, technologically mediated ecological learning systems. Theories such as Chatman's life in the round (Chatman, 1999, 2000) and Fisher's information grounds (Fisher *et al.*, 2004; Fisher and Naumer, 2006) further emphasize the complexity of how information surrounding learning and knowledge is transmitted and shared across and within specific, sometimes siloed, contexts.

Though digital badges can function as boundary objects, boundary crossing may also not always be desired by the members of learning communities (Bowker and Star, 1999; Star and Griesemer, 1989). Placing an emphasis on digital badges as shareable and transferrable to other contexts assumes that learners want to share and transfer their learning across settings, but individuals, particularly young people, may want to maintain separate identities across contexts. Goffman (1959) discusses the different identities individuals form for different spaces in their lives, and though social technologies in recent years have made it easier for people to connect different contexts, people still present themselves differently at work and at play, and thus may resist boundary crossing via digital badges. For instance, Hickey *et al.* (2015) discuss how digital badges have been found to function well in specific, informal settings, but run into barriers of credibility and acceptance when organizations attempt to formalize or generalize digital badging practices. Considering the social implications of information behaviors may aid in understanding why badges might have difficulty gaining a foothold in certain learning contexts, and from there allow us to develop better systems.

Though learning settings may be increasingly interconnected, technology has also provided opportunities for groups to create tight-knit information communities with limited outside connections in virtual spaces as well as physical ones (Savolainen, 2009). While the recent pervasiveness of mobile and social networked technologies has made certain STEM communities technically less gated, much of their restricted nature is socially constructed (Savolainen, 2009). Boundary crossing into or out of these groups or organizations may be seen as a violation of social mores or a collapsing of contexts intended to remain separate. Thus, one can see how informational boundary objects such as digital badges can face a variety of challenges in broader acceptance due to the way informal information and learning spaces are socially constructed and upheld.

2.4. Expanding science, technology, engineering and mathematics trajectories with digital badges

Digital badges have emerged in recent years as a new type of credential – or microcredential – whose form and uses align with a multiple pathways approach to STEM

learning. Unlike grades on a transcript, which consolidate all learning experiences into a singular, culminating "score," digital badges offer a more fine-grained view of the individual accomplishments that a learner demonstrated during the course of a learning experience. As a result, learners can see where their strengths and interests lie, as well as what gaps remain in their learning. By making learning pathways visible in this way, badges can help set learners on a path to future learning and career opportunities (Riconscente *et al.*, 2013).

Multiple studies have established that digital badges can have positive effects on learners' motivations, engagement and identity formations within the learning contexts where they are employed (Abramovich *et al.*, 2013; Chou and He, 2017; Denny, 2013; Plass and Homer, 2015; Restivo and van de Rijt, 2012). For instance, in two separate controlled experiments, Denny (2013) and Restivo and van de Rijt (2012) found positive effects of badges on students' levels of participation in an online learning platform and on contributors' productivity levels on Wikipedia, respectively. In their study of badge use in an online graduate teacher education program, Chou and He (2017) found that badges were most effective at enhancing student interaction in traditional, as opposed to activity-based, online courses. The researchers found no effect of badges on students' levels of participation.

Prior work suggests that not all learners respond the same way to badges. For instance, Abramovich *et al.* (2013) studied the use of digital badges among middle school students who used a cognitive tutor in a math class for one month. They found that the effects of badges varied according to students' levels of prior knowledge, as well as the type of badge earned. Participatory badges were more aligned with extrinsic motivation, whereas skill badges were more aligned with intrinsic motivation. Other researchers have found similar differences in the effect of badges according to learner characteristics, learning context and type of badge awarded (Boticki *et al.*, 2015; Filsecker and Hickey, 2014; Plass and Homer, 2015). This work suggests that digital badges are not a panacea for creating equity across every community. However, badges do offer an opportunity for broader inclusion across multiple contexts because they can be used to recognize achievements in any learning environment or workplace provided the proper infrastructure is in place (Hickey *et al.*, 2015; Hickey and Schenke, 2018).

As the preceding review suggests, the bulk of existing research on digital badges has focused on their value within specific learning contexts. Indeed, Hickey *et al.* (2015), in their review of 29 early badge initiatives, concluded that at present, badges have worked better *within* rather than *across* learning contexts. Although internal uses are certainly valuable – as prior work demonstrates – focusing solely on building the internal value of badges fails to take advantage of their full potential. This potential involves giving young people the ability to share with audiences of import a range of skills they have acquired in a variety of learning contexts (Fishman *et al.*, 2018). For instance, we currently lack mechanisms for documenting and showcasing key 21st century skills, such as collaboration, leadership and problem-solving, which are increasingly valued by the labor economy (Deming, 2017). Moreover, those students who receive the greatest support for packaging such skills in a recognizable way are typically the students who already have access to the greatest educational opportunities (Davis and Singh, 2015; Davis and Fullerton, 2016; England, 2017). Badges have the potential to increase equity by providing all learners with the means to showcase a broad range of accomplishments for key stakeholders such as college admissions officers and employers, but only if implemented appropriately, without perpetuating or amplifying the existing inequalities created by socioeconomic and other factors (Fishman *et al.*, 2018).

Also lacking are standardized mechanisms for validating accomplishments that occur outside typical institutional standards or benchmarks. By recognizing these

accomplishments, badges are compatible with the theoretical notion of achieving success across and through multiple trajectories that lead to STEM-related occupations (Cannady *et al.*, 2014). In this way, badges offer the potential to support a wider range of learners entering the STEM workforce. They challenge the pipeline metaphor by expanding and diversifying the possibilities for young people across communities to follow their own trajectories into STEM-oriented fields of study. However, without measures in place to prevent affluent students and users from gaining excessive advantages, badges cannot serve an equitable purpose. Thus, those implementing badge systems must consider equity in all aspects of their research and development or risk merely continuing the status quo.

The current study fills a need for research that investigates the use of digital badges across – as opposed to within – contexts while drawing on information behavior theory to understand the challenges of doing so. Roy and Clark (2018) stress a need for further research into the broader effects of digital badges in their review of recent research. By documenting the perspectives of higher education and employment gatekeepers, we explore whether badges can help to increase and diversify the STEM workforce by expanding the types of trajectories that lead to STEM-oriented careers.

3. Method

3.1 Research participants

We recruited college admissions officers from within Washington State and human resources and hiring personnel from Seattle-area technology companies. Due to the focus of the research and the student population with which we were working, local businesses in STEM fields and undergraduate institutions were most relevant. We compiled a comprehensive list of public and private higher education institutions in Washington State and invited admissions representatives from the list to participate in an interview. We identified human resources representatives from a list of established contacts from Seattle-area technology companies. We purposively selected participants from these lists in an attempt to create samples that were broadly reflective of the range of higher education institutions in Washington State and technology companies in the Greater Seattle area.

The final participant group consisted of 19 college admissions officers, counselors or other positions involved in the admissions process and 11 representatives of Seattle-area technology companies, such as human resources professionals, recruiters or equivalent positions. The college admissions officers represented a variety of college types including public universities (five), private colleges and universities (seven) and community and technical colleges (seven). The institutions varied in size, admissions criteria and selectivity. The employer sample included representatives from eight different companies, ranging from small technology startups to large multinational corporations. All participants were recruited via email and provided with information regarding the project and consent documents prior to the interview.

3.2 Procedure

Two researchers conducted the interviews between August 2015 and May 2016. All but one of the interviews were conducted via phone (the other was conducted in person). Prior to their interview, participants received a document that summarized digital badges and provided screenshots of the badge system that our research team was in the process of developing for an afterschool science program. This approach helped to make the ideas raised and questions asked in the interview more concrete, as many participants had little to no prior experience with badges. The badge system prototype served as an orienting tool and was not the main focus of the interview. Each interview used the same semi-structured

protocol based on the last author's prior research (Davis and Singh, 2015), adjusted for either a college admissions or hiring context. Participants were asked about the nature of their work; their familiarity with digital badges prior to the interview; and their candid opinions about digital badges, including both perceived challenges and opportunities. The interviewers took field notes and recorded each interview for later analysis. Interviews were then transcribed verbatim and imported into qualitative data analysis software.

3.3 Analysis

Members of the research team conducted a thematic analysis of the interviews (Boyatzis, 1998). We adapted a coding scheme developed by the last author in prior work investigating stakeholders' perceptions of the opportunities and challenges of digital badges (Davis and Singh, 2015). The codes address participants' prior knowledge of and experience with digital badges; perceived opportunities; perceived challenges; and an overall assessment of participants' views of digital badges (i.e. generally positive, generally negative or ambivalent). Several codes were added to the coding scheme based on emergent themes. For instance, *using badges to identify and sort students* represented an opportunity discussed by some participants in the current investigation that was not reflected in the initial coding scheme.

To ensure that codes were applied consistently and accurately, the researchers performed several rounds of consensus coding (Smagorinsky, 2008) to achieve agreement on the definition and appropriate application of each code. Transcripts were divided into segments, with each segment representing a complete thought or utterance, and then coded at this level of granularity to calculate interrater reliability. This process involved three researchers coding the same interview independently, and then coming together to discuss areas of disagreement. Consensus was reached through discussion of conflicting codes and resolution of disagreements (Smagorinsky, 2008). This process was conducted with seven transcripts, after which we felt confident that the coding scheme was clearly defined and understood by all researchers.

After a two-month interval, two researchers independently coded the same seven transcripts to ensure consistency and accuracy in code application within and between coders. For this round of coding, we calculated reliability scores for each code using Cohen's kappa statistic, setting the threshold at 0.7, well above acceptable levels established in prior work (Landis and Koch, 1977). In the final stage of coding, one of the researchers coded the remaining transcripts with periodic coding checks performed by other research team members, including the last author.

4. Results

4.1 Stakeholders' familiarity with and perceptions of digital badges

Although many of the stakeholders we interviewed did not have direct experience with digital badges, 47 per cent (14) had at least heard of digital badges, having read or conversed with colleagues about them. Of the remaining interviewees, 20 per cent (6) had directly used badges and were aware of their uses, while 33 per cent (10) stated that they were unfamiliar with badges prior to participating in the current study. These proportions were similar across our two stakeholder samples (college admissions officers and employers).

With respect to general perceptions of digital badges, 70 per cent (21) of the stakeholders expressed an overarching enthusiasm for digital badges during their interviews, while 27 per cent (8) were more mixed in their reactions and only 3 per cent (1) seemed extremely skeptical of the idea. Stakeholders were particularly interested in the possibility of using badges to illuminate applicants' soft skills, such as leadership, collaboration and

communication skills. In fact, when discussing those skills that lend themselves most readily to badging, participants discussed soft skills more frequently than content-based or technical skills.

4.2 Perceived strengths of digital badges

Throughout the interviews, participants' references to challenges and opportunities were fairly balanced, with 137 references to opportunities and 150 references to challenges. The most commonly mentioned opportunities were:

- the use of badges to establish the credibility of learners' accomplishments (29.9 per cent of all references to opportunities);
- the ability to use badges to identify and support learning trajectories (13.1 per cent); and
- using badges to identify and sort students and applicants (13.1 per cent).

Other opportunities that arose frequently included support for assessment practices (7.3 per cent) and the promotion of social equity (5.1 per cent) (Table I). In the following sections, we focus on frequently cited opportunities and challenges that most directly address our guiding focus on the potential for digital badges to support learners' STEM-oriented learning and career pathways.

4.2.1 Establishing one's credibility. Stakeholders most frequently mentioned the potential for badges to establish the credibility of an applicant's skills and experiences, as "the micro credential is actually really transparent," and could provide valuable details about an applicant's experiences and competencies. One private university admissions officer discussed the validation of soft skills using digital badges:

> The idea of badges that get to whether it's public speaking or being part of a group project that was successful or a student doing an independent research project, getting some real data about a student's resourcefulness and independence but also teamwork would be great, [. . .] And having that be evidence based and having a valid issuer, a trusted source that was giving it [. . .] would be great.

This stakeholder focused on skills that might not be typically measured in test scores or other application materials, and thought that a validated way of representing these skills would be useful to their admissions processes. Another college admissions officer emphasized how the badges could provide them with "what kind of commitment [the applicant] put into [the activity represented by the badge] outside of school".

Employers were also interested in having a validated, credible record of an applicant's technical skills. One human resources professional, who hired for highly technical positions,

Opportunity	Overall	Colleges	Employers
Credibility	29.9% (41)*	23.9% (21)	40.8% (20)
Sorting Applicants	13.1% (18)	3.4% (3)	30.6% (15)
Learning Pathways	13.1% (18)	13.6% (12)	12.2% (6)
Assessment Practices	7.3% (10)	10.2% (9)	2% (1)
Supports Equity	5.1% (7)	7.9% (7)	0% (0)

Note: *Counts and percentages refer to the number of times an opportunity was discussed across all interviews

Table I. The five most frequent badge opportunities discussed by interview participants

explained how digital badges might be more useful than the current system of evaluating skillsets:

> [. . .] it sounds like you would be able to maybe have a more detailed idea of what that individual really knows other than, like, if I'm looking at a resume and my job description says they're looking for Python and they're looking for C sharp, right? And they have that listed, they usually don't have a lot of information about the depth of what they've done.

This employer noted that even if an applicant has a certain programming skill listed, there may not be enough information about their depth of skill to adequately assess their appropriateness for the position. Thus, badges that provide more granularity and validation to the picture of the applicant's skillset might be of great use to employers.

4.2.2 Making learning pathways visible. Stakeholders discussed ways that digital badges could help to create visible learning pathways and trajectories of students' and applicants' achievements, such as by providing increased granularity and transparency. With respect to *granularity*, participants noted the benefits of breaking learning achievements into smaller components and recognizing each one through microcredentials. With respect to *transparency*, participants believed that digital badges would allow them to examine applicants' learning trajectories in detail, noting how and when each step in the pathway was achieved. They believed that such a granular, transparent approach would provide a more accurate and complete understanding of students' and applicants' preparation. This perception was particularly salient in discussions of soft skills, which participants generally felt were currently more difficult to interpret than subject matter knowledge. For instance, one college admissions officer at a private college stated:

> We usually only get a real picture of that [the skills gained] from teacher evaluations, because most essays don't really go into soft skills and most extra-curricular lists just list what was done and not the skills that were gained. So, to me, I think the soft skills would be this really nice pairing with the extra-curricular list and a teacher evaluation or another form of evaluation.

For this admissions officer, badges hold the potential to provide a "real" picture of applicants' soft skills by enumerating the specific skills gained from their participation in various learning experiences. This level of detail and specificity makes them more valuable than a list of extracurricular activities.

College admissions officers mentioned that the visibility of applicants' learning pathways would allow them to make more nuanced decisions in the admissions process. One public university official pointed out that badges would enable reviewers to see students' microcredential trajectories, particularly those students who might be considered borderline. He explained:

> It's the students who are sort of in that middle space where that would become a lot more interesting because especially if [the badges] were earned late in their academic career or their academic career had shown that this was something that they'd moved into and had begun to demonstrate sort of expertise or interest in these areas.

This admissions officer appreciated how badges might help students demonstrate the pathways they have taken during their academic career, including how their academics and personal growth have evolved over time. Unlike grades on a transcript, such a view would allow those evaluating applications to see students' learning trajectories clearly.

College admissions officers highlighted a degree of detail that was not generally present in standard applications, while employers were particularly intrigued by the idea of being able to see very specific technical and soft skills that applicants had acquired and wanted to stand out in their applications. As one participant pointed out, "[. . .]one thing they

[technology companies] are super familiar with is the idea of a micro-competency and the way you can put borders on anything you can do in that discipline." Human resources professionals mentioned that badges might be able to distinguish between levels of technical skill in specific programming environments and systems.

4.2.3 Improving efficiency. Participants in both stakeholder groups stated that badges could be a quick, visual way to review applications and sort applicants. With the volume of applications received in both academia and industry, efficiency is key to many workflows. One community college admissions officer observed:

> The admissions offices are typically looking for a way to automate things. And so, unless there was like a comprehensive database, these badges can give you these points in your admissions process if the officers were willing to put in the work to make that happen.

Employers were perhaps even more eager to use badges as a sorting tool and thought that the ability to sort visually made badges a possible way to increase efficiency in the application process. One employer stated,

> [. . .] I think in a lot of what we do, that first screening is you're looking it over, you're seeing if they have the qualifications, and I think it would be helpful to have something visual versus five pages of text.

Another employer focused more specifically on the visual shorthand that badges could provide human resources managers, explaining:

> I imagine that it could be much easier just to very quickly evaluate a candidate like we know what this badge looks like; it's very clear and easy to identify it.

These stakeholders repeatedly highlighted the convenience of the badges as a visual sorting tool.

4.2.4. Supporting alternative assessment practices. College admissions officers in particular noted that they are consistently seeking ways to ensure their process for assessing applicants is both efficient and holistic. One private college admissions officer explained that they were always looking for the next way to assess which students to select, and:

> [. . .] if badges could be a way of identifying skill sets in students that are really meaningful to student success that other colleges don't pay attention to, it gives us an edge at finding talent.

Another university employee explained that badging might be a good alternative to selecting students based on testing and other common forms of assessment:

> [. . .] the general sense is that the placement testing is a necessary evil and any alternative we can find to using it is a good one, a good thing. I think that's probably where they would go with [badges]. And then scholarships would be the other piece, how can we use these [badges] to help students get scholarships.

This college admissions officer wanted to use digital badges in multiple ways, not only as part of his institution's assessment practices but also in financial aid and scholarships, illustrating how participants imagined badges being integrated into complex workflows.

4.2.5 Supporting equity. Five stakeholders observed that badge systems could be used to display skills, talents and experiences that might not otherwise be visible in standard applications, giving students and applicants with non-traditional backgrounds and socioeconomic disadvantages a chance to explain and authenticate their unique experiences. In discussing the potential of digital badges, one college admissions officer at a private college said:

> I would want [badges] to be something that would be accessible to students regardless of their financial means. So that's something I see similar to what [our college is] trying to accomplish with our effort at gathering information about non-cognitive characteristics that are predictive of success.

This admissions officer saw badges as being well aligned with his institution's focus on building a more complete, holistic picture of applicants by emphasizing non-cognitive characteristics, which are skills that support both academic and workplace success like motivation, perseverance and teamwork. This focus on authenticating a diverse set of experiences in an accessible manner is a way in which badges might be used to support equity in the learning process.

Several stakeholders were intrigued by the potential of badges and badge systems to help students display their skills and experiences in a professional, compelling manner and prepare them for future educational and employment endeavors. Currently, it is the students in more affluent neighborhoods and well-resourced schools who typically receive such support, and it is important to not perpetuate and amplify these disparities with new technologies. An official from a community college board discussed how certain community colleges are looking to use badges to support their college preparatory programs:

> [Community colleges] are interested in badges because some of their programs are non-credit programs. In Basic Ed, there could be some momentum around badges if it were presented correctly, because they're always looking for, well, everything from flipped classroom to competency-based to any kind of new way to get them ahead for the Basic Ed learners and motivate them to achieve college readiness in the least expensive and most effective way possible.

This official not only focused on how badges would support equity from a financial perspective by helping achieve college readiness inexpensively but also expressed the idea of competency and incorporating badges representing skills learned outside of schools into more formal settings. Due to his position working within a system of community colleges, this participant expressed a broader view than many of the other stakeholders interviewed. As a result, he was able to reflect on the workflow of community colleges as a whole and consider how badges might be used to prepare nontraditional students for future college programs.

4.3 Challenges of implementing digital badges

Stakeholders were most concerned about establishing the credibility and authority of digital badges (39.3 per cent of all referenced challenges) (Table II). Another major challenge that participants foresaw was the time, effort and money required to implement and use badges (28 per cent), noting the significant adjustment to existing workflows that badges would require. Related to their concerns about credibility, participants also expressed concern about the possible triviality of badges (10.6 per cent), due to the decentralization of issuers

Table II.
The three most frequent badge challenges discussed by interview participants

Challenge	Overall	Colleges	Employers
Credibility	39.3% (59)*	40.2% (43)	37.2% (16)
Integrating into Workflows	28% (42)	26.2% (28)	32.6% (14)
Triviality	10.6% (16)	8.4% (9)	16.3% (7)

Note: *Counts and percentages refer to the number of times an opportunity was discussed across all interviews

and the possibility of issuing badges based on "showing up" instead of demonstrating specific skills.

4.3.1 Credibility concerns. More than any other possible barrier to implementation, participants raised the challenge of getting others to recognize digital badges as a credible source of certification. Discussed by 24 of the 30 (80 per cent) participants, credibility concerns accounted for 39 per cent of all references to challenges across the entire set of interviews. College admissions officers were concerned that some badges would not come from credible authorizing bodies. As one of the community college admissions officers explained:

> I mean the biggest thing is how do you verify and know that that student was the one that went through that training and this really is their badge and those type of pieces?

One admissions officer at a public university was particularly concerned that some badges might be falsified, explaining his line of reasoning, "[. . .]how can we prove that these badges are official badges and that they haven't been counterfeited or created by a third party not authorized to award them?" Another mentioned the difficulty of getting the badges accepted by faculty, who might "ask why we're looking at anything that's not specifically academic in nature".

Employers also struggled with the credibility of digital badges, the question of "who's behind that stamp of approval?" They wanted to take advantage of this new resource, but worried about the wider acceptance of it by their professional communities. One participant was a co-founder of a startup that provided companies with interviewers for highly technical positions. He drew a direct comparison between the challenges that his startup faced as they sought to establish themselves in the field and the challenges of establishing badge credibility:

> It's actually like [our startup is] going through a very similar thing right now [. . .] how will we prove our value in the future as a company? One of the ways we think we'll do that is by having this super high bar for who becomes an interviewer on our platform [. . .] So I see that accreditation and what's attached to it, what does this really mean, would be very important [to digital badges].

This particular company prides itself on providing skilled interviewers for technology companies, and thus the participant had a nuanced perspective on the struggle of establishing credibility to external audiences.

4.3.2 Integrating into existing workflows. The amount of work and resources required to incorporate digital badges into existing workflows accounted for 28 per cent of all challenge references. Participants expressed concern about the amount of time and money needed to introduce badges at scale. Integrating a new component into an already time-intensive process such as hiring and college admissions was viewed as extremely difficult. Related to their concerns about establishing credibility, some admissions officers reflected on the effort required to establish widespread adoption of badges. As one private college admissions representative reflected:

> I think especially in the beginning, before people know what a badge means and know much about digital badges in general, it would require a lot more effort on our part to review them and get a sense of what they mean.

Admissions officers also considered the shifts in their workflow to be an issue. Disruptions to an established system can be difficult and time consuming. As described by an admissions officer from a public university:

> The additional workload of thinking about how to process them and the kind of systematic logistics of that would be definitely something worth considering, right, if we had to download a list of badges every week and print them and add them. But you wouldn't even want to print them.

For this particular university, print applications were still part of the admissions workflow, so adding something that was meant to be purely digital would introduce a nontrivial challenge.

Added time was also a concern among participants. Many admissions officers and hiring staff stated that they were perennially short on time and did not necessarily want to add another step to their processes. As one hiring representative said:

> I guess my only concern would be opening something else because it's already several clicks to get to the PDF file to open up a resume. My time is so limited because I work about 12-13, 14 hours a day as it is and I can't get through my pipeline.

Generally, stakeholders had fairly serious concerns about how badges would be implemented in their workplaces and integrate into their institution's existing workflow.

4.3.3 Separating the wheat from the chaff. Related to their concerns about credibility, stakeholders were also concerned with issues of quality and triviality, "determining what counts as badge worthy." If they were going to adopt badges, stakeholders wanted to ensure that the badges were meaningful and of high quality, representative of significant experience or skill. Stakeholders worried that applicants would place greater emphasis on badges that "have good brand recognition" rather than "putting down badges that represent actual hard-earned or difficult to acquire knowledge and skill sets," as one public university admissions official put it. Another admissions officer, from a community college, was concerned about the possibility of a situation reminiscent of a diploma mill:

> Are we going to have badge mills in the future? I think that this has been because a lot of people are unfamiliar with the badges that they just get cranked out and they may or may not be all that meaningful for a student. So, I think that's going to be some of the work that needs to be done around helping badges be accepted.

Employers also felt that badges might not provide enough information or be of high enough quality and granularity to discern among applicants. One employer stated:

> There's always going to be if you have several of them with that same badge [. . .] how do I know who was the top of that, of the recipients of those badges, and who was making the call or certifying them and what credentials does that person have?

As previously mentioned, employers saw the potential for badges to sort applicants and provide a granular view of their learning pathways, but this participant was concerned that badges might not go far enough.

5. Discussion

In this study, we examined college admissions and employer stakeholders' perspectives on the potential for digital badges to support learners' STEM-oriented career pathways across settings. This work closely interrogates the concept of the oft-mentioned STEM pipeline and how multiple-pathway models can better accommodate the diverse range of experiences and interests that students bring to STEM education and career opportunities (Bricker and Bell, 2014; Cannady *et al.*, 2014). To that end, our perspective is informed by the more flexible learning ecologies and cultural learning pathways models that allow for multiple entry points to STEM fields (Barron, 2006; Bricker and Bell, 2014), unlike a pipeline that can be

both exclusionary and "leaky" (Cannady *et al.*, 2014). Information behavior theories also provide insight into the challenges of using digital badges as *boundary objects* (Bowker and Star, 1999; Star and Griesemer, 1989) across different informal learning settings that might not wish to accept outside credentials (Chatman, 1999, 2000; Fisher *et al.*, 2004; Fisher and Naumer, 2006; Savolainen, 2009).

In this investigation, we interviewed 30 employers and college admissions officers to garner their perspectives on digital badges and how badges might support students' STEM learning and career pathways. These stakeholders generally expressed positive opinions about digital badges and found them to be useful in terms of their ability to display students' learning trajectories. This paper contributes evidence that digital badges have the potential to acknowledge and authenticate the skills of young people from nontraditional learning backgrounds both within and *beyond* the communities in which they earned their badges. At the same time, sharing credentials across disparate settings raises distinct challenges, as not all of these groups welcome outside knowledge or status, preferring their own bounded and defined notions of expertise, which we can see in our stakeholders' discussions of credibility (Chatman, 1999, 2000; Fisher *et al.*, 2004; Fisher and Naumer, 2006; Savolainen, 2009). Though digital badges can serve as information-rich boundary objects (Bowker and Star, 1999; Star and Griesemer, 1989), to function as such, they must carry credible weight between the different worlds in which they act. Thus, we can see how credibility was considered both one of the greatest opportunities and one of the greatest challenges by our interviewees. There is great potential for boundary crossing with microcredentials, but digital badges need to be legitimated in these diverse settings for them to function as intended.

The results of our analysis suggest that digital badges can support STEM learning pathways through visibility, credibility and equity. Badges increase the *visibility* of students' learning pathways (Riconscente *et al.*, 2013), showing the specific steps that students took to gain a particular certification or skill. They also allow a broader range of skill types to be represented and accredited, including the much-discussed soft skills such as teamwork, motivation and perseverance. Giving *credibility* to these skills and making them clearly visible as part of a resume would be advantageous, particularly to those students who gained their soft skills outside of a formal academic setting. Using badges to showcase and connect students' learning across settings could also support *equity* in STEM learning and career opportunities. In particular, students could demonstrate skills acquired outside of formal institutions, thereby allowing for the possibility that multiple STEM pathways are considered in admissions and hiring decisions (Spaulding and Johnson, 2016; Tyson and Roksa, 2016; Wyn *et al.*, 2017). Thus, digital badges can function as *boundary objects* (Bowker and Star, 1999; Star and Griesemer, 1989) with rich metadata, transferring the representations of skills across settings. Our findings suggest that stakeholders see a great deal of potential in badges to break down some of the walls between disparate learning communities and make STEM leaning more equitable by allowing learners to gain access to new groups with alternative credentials. The opportunities discussed by the stakeholders in this study were similar to those identified in previous work (see, for example, Davis and Singh, 2015; Grant, 2016; Hickey *et al.*, 2015; Riconscente *et al.*, 2013).

Admissions officers at community colleges had their own particular interest in digital badges in addition to the possibilities discussed above. Community colleges are an important pathway to STEM education and careers that can sometimes be ignored by the pipeline model (Hagedorn and Purnamasari, 2012). The admissions officers at these institutions viewed digital badges as a support for students' learning trajectories as they developed their skills. They also regarded badges as a potential tool to prepare students for

further education, such as transfers to four-year institutions. Whereas admissions officers working at public and private four-year colleges and universities tended to discuss badges as a tool to use in evaluating applications, officers at community colleges were more likely to see uses beyond the initial evaluation of students.

Although digital badges have great potential to support learners' STEM pathways, there are challenges to their implementation and integration into existing application structures. In terms of credibility, triviality and logistics, there is still work to be done before badges can gain broader traction. *Credibility*, one of the possible advantages of badges, is also a point of tension, raising questions about who is developing the credentials and the equity issues embedded therein. When trying to promote diversity and allow for more pathways into STEM careers, colleges and employers must consider how they plan to adjust to these new perspectives and workflows. The communities that digital badges attempt to connect via their boundary crossing may not be easily brought together, as these distinct communities may not recognize or value credentials coming from other communities (Chatman, 1999, 2000; Savolainen, 2009). The *logistics* of implementing badges can be difficult, and it may be particularly difficult to convince an organization to change its procedures when dealing with a technology like digital badging, which many do not yet perceive as credible. Related to credibility, there is also a concern of issuing *trivial* badges, with some interview participants suggesting badge mills or video-game-like achievements that are essentially meaningless. These concerns may slow the adoption of digital badges as recognized forms of accreditation (Hickey *et al.*, 2015; Riconscente *et al.*, 2013). These challenges indicate that there are still strong boundaries between STEM education communities, with each valuing its own knowledge base and credentials (Chatman, 1999, 2000; Fisher *et al.*, 2004; Fisher and Naumer, 2006; Savolainen, 2009). Thus, the challenges we have discussed support the idea that badges as boundary objects may have difficulty gaining acceptance in particularly bounded groups.

There is also some tension between how employers and admissions officers may view badges, on the one hand, and the intentions of those seeking to use badges to promote diversity and equity, on the other. As with any credential, badges have the potential to be used as a sorting tool or as another benchmark for an applicant to pass to be considered. Several stakeholders in this study described the advantages of using badges in this way, noting that having access to a sorting tool would make their processes more efficient. This perspective underscores the fact that, while the current work considers how badges might promote multiple pathways to STEM careers and disrupt the school-to-workforce pipeline model, others may have different perspectives on badge use. Using badges to sort and select students reifies rather than disrupts the pipeline model. It is important to acknowledge the possibility that introducing digital badges may be unwittingly perpetuate and replicate the existing sorting systems that privilege some students over others.

We posit the following guidelines for those interested in developing or implementing badge systems of their own. These recommendations follow prior work on digital badge design, such as (Hickey *et al.*, 2015), but focus more on how badges can be used to cross boundaries and establish credibility. We suggest the following, based on our interview findings:

- Digital badges must support and establish the credibility of diverse learning pathways both within and across contexts.
- Digital badges must be credible and meaningful (not trivial) to all stakeholders to be accepted across contexts.
- Stakeholder support and willingness to commit time and effort are crucial for successful badge implementation.

- Digital badge systems must easily integrate into existing application workflows to function to their full potential.
- Digital badge systems must incorporate equity throughout all stages, or risk perpetuating or even amplifying existing inequities.

While these guidelines are broad and preliminary, we hope that they provide some guidance for those interested in designing and implementing digital badges as supports for learners' STEM pathways.

5.1 Implications

The insights gained from this study have implications for a number of stakeholders associated with using badges to support diverse STEM learning and career pathways. As *researchers*, we must evaluate how our work to promote equity in STEM learning may not always be interpreted as we imagine. To this end, we should continue discussions of ethics and equity and create an ongoing conversation with the public and key stakeholders about how these values can be incorporated throughout the system. Badge *issuers* and *developers* must consider a variety of logistical issues, such as how to prove the credibility of their badges to stakeholders and how to make sure that their products integrate into existing workflows of other organizations. For their part, *colleges* and *universities* will need to consider how to incorporate badges into their workflows efficiently and possibly coordinate on a larger scale to allow badges to transfer between institutions. Badges could make processing applications and working with different community colleges and institutions easier in the long term, but initial implementation will be challenging. *Employers* could use badge pathways in a variety of areas, including professional development as well as applications, but again we must consider the possibility that badges will be used to sort applicants rather than provide more diverse pathways for entry. *Students* and *job applicants* may find badges useful for visualizing and documenting their own STEM learning pathways (Bell and Davis, 2016; Davis and Fullerton, 2016; Klein and Davis, 2016), but it may take longer for their badges to be recognized formally by colleges and employers. Still, badges can provide a clear visual for evaluators to understand an applicant's trajectory, which in turn can promote equity by allowing all students to represent their achievements. In future work, we hope to develop a clearer understanding of how badges might be implemented effectively to connect learning across settings.

5.2 Limitations and future directions

The sample in this study presented a variety of perspectives from technology-focused workplaces and diverse educational institutions. At the same time, we acknowledge that the sample was geographically limited and relatively small. In future work, we hope to expand beyond the current geographic area and examine a more diverse range of employers, including a broader range of STEM-focused companies. Although we did include diverse college types, a wider sample of colleges from across the USA would also be beneficial in future work.

The prototype badge platform used in these interviews provided participants with an "object to think with" (Turkle, 2007) intended to stimulate their thinking about digital badges. However, because it was specific to an afterschool science program for high school students, it may not have been directly relevant to all participants. While there is some concern about priming their views on digital badges, there was no indication of any significant change in perspective other than increased familiarity with badges. Additionally, phone interviews may not have provided the optimal environment for explaining and

demonstrating the prototype system. Face-to-face interviews would have allowed researchers to point out certain elements of the interface more readily. In future work, we plan to use a functioning badge system to allow participants to engage directly with the system and understand how it works in a far more concrete way.

6. Conclusion

Prior work has explored how learning pathways can be supportive of students' STEM learning and how digital badges can be a method of visualizing learning pathways across contexts (Davis and Singh, 2015; Klein and Davis, 2016; Riconscente *et al.*, 2013). The current work investigated how stakeholders in academia and the job market view the potential of digital badging as a support for STEM learning pathways and how these pathways can promote equity for a more diverse group of learners. Stakeholders were generally enthusiastic about the prospect of incorporating badges into the college admissions and hiring processes, but they nevertheless identified several notable challenges that must first be overcome. They also surfaced thoughts about using badges as a sorting tool for applicants that would seem to reify rather than disrupt the school-to-workforce pipeline model. The findings from this study reveal that while digital badging systems have strong potential to support STEM learning pathways in a more equitable manner, allowing more entry points to STEM careers, there are still both logistical and ideological barriers to stakeholders fully embracing digital badges.

References

Abramovich, S., Schunn, C. and Higashi, R.M. (2013), "Are badges useful in education? It depends upon what type of badge and expertise of learner", *Educational Technology Research and Development*, Vol. 61 No. 2, pp. 217-232.

Adamuti-Trache, M. and Andres, L. (2008), "Embarking on and persisting in scientific fields of study: cultural Capital, gender, and curriculum along the science pipeline", *International Journal of Science Education*, Vol. 30 No. 12, pp. 1557-1584.

Cannady, M.A., Greenwald, E. and Harris, K.N. (2014), "Problematizing the STEM pipeline metaphor: is the STEM pipeline metaphor serving or students and the STEM workforce?", *Science Education*, Vol. 98 No. 3, pp. 443-460.

Barron, B. (2006), "Interest and self-sustained learning as catalysts of development: a learning ecology perspective", *Human Development*, Vol. 49 No. 4, pp. 193-224.

Bell, A. and Davis, K. (2016). "Learning through participatory design: designing digital badges for and with teens", *Proceedings of the The 15th International Conference on Interaction Design and Children*, ACM, New York, NY, pp. 218-229, available at: https://doi.org/10.1145/2930674.2930705

Boticki, I., Backsa, J., Seow, P. and Looi, C.-K. (2015), "Usage of a mobile social learning platform with virtual badges in a primary school", *Computers and Education*, Vol. 86, pp. 120-136.

Bowker, G.C. and Star, S.L. (1999), *Sorting Things out: Classification and Its Consequences*, MIT Press, Cambridge, MA.

Boyatzis, R.E. (1998), *Transforming Qualitative Information: Thematic Analysis and Code Development*, Sage, New York, NY.

Bricker, L.A. and Bell, P. (2014), "What comes to mind when you think of science? The perfumery! documenting science-related cultural learning pathways across contexts and timescales", *Journal of Research in Science Teaching*, Vol. 51 No. 3, pp. 260-285.

Bronfenbrenner, U. (1979), *The Ecology of Human Development: Experiments by Design and Nature*, Harvard University Press, New York, NY.

Chatman, E.A. (1999), "A theory of life in the round", *Journal of the American Society for Information Science*, Vol. 50 No. 3, pp. 207-217.

Chatman, E.A. (2000), "Framing social life in theory and research", *New Review of Information Behaviour Research*, Vol. 1, (December), pp. 3-17.

Chou, C. and He, S. (2017), "The effectiveness of digital badges on student online contributions", *Journal of Educational Computing Research*, Vol. 54 No. 8, pp. 1092-1116.

Crowley, K. and Jacobs, M. (2002), "Islands of expertise and the development of family scientific literacy", in Leinhardt, G., Crowley, K. and Knutson, K. (Eds), *Learning Conversations in Museums*, Lawrence Elbaum Associates, Mahwah, NJ, pp. 333-356.

Davis, K. and Fullerton, S. (2016), "Connected learning in and after school: exploring technology's role in the learning experiences of diverse high school students", *The Information Society*, Vol. 32 No. 2, pp. 98-116, available at: https://doi.org/10.1080/01972243.2016.1130498

Davis, K. and Klein, E. (2015), "Investigating high school students' perceptions of digital badges in afterschool learning", *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, ACM, New York, NY*, pp. 4043-4046, available at: https://doi.org/10.1145/2702123.2702413

Davis, K. and Singh, S. (2015), "Digital badges in afterschool learning: documenting the perspectives and experiences of students and educators", *Computers & Education*, Vol. 88, pp. 72-83, available at: https://doi.org/10.1016/j.compedu.2015.04.011

Deming, D.J. (2017), "The growing importance of social skills in the labor market", *The Quarterly Journal of Economics*, available at: https://scholar.harvard.edu/files/ddeming/files/deming_socialskills_may2017_final.pdf

Denny, P. (2013), "The effect of virtual achievements on student engagement", *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, New York, NY*, pp. 763-772.

England, J. (2017), "Confessions of an admissions officer", *The Chronicle of Higher Education*, available at: www-chronicle-com.offcampus.lib.washington.edu/article/Confessions-of-an-Admissions/241919

Filsecker, M. and Hickey, D.T. (2014), "A multilevel analysis of the effects of external rewards on elementary students' motivation, engagement, and learning in an educational game", *Computers and Education*, Vol. 75, pp. 136-148.

Fisher, K.E. and Naumer, C.M. (2006), "Information grounds: theoretical basis and empirical findings on information flow in social settings", *New Directions in Human Information Behavior*, Springer, Dordrecht, pp. 93-111.

Fisher, K.E., Durrance, J.C. and Hinton, M.B. (2004), "Information grounds and the use of need-based services by immigrants in Queens, New York: a context-based, outcome evaluation approach", *Journal of the American Society for Information Science and Technology*, Vol. 55 No. 8, pp. 754-766.

Fishman, B. Teasley, S. and Cederquist, S. (2018), "Micro-credentials as evidence for college readiness: report of an NSF Workshop", available at: https://deepblue.lib.umich.edu/handle/2027.42/143851

Gibson, D., Ostashewski, N., Flintoff, K., Grant, S. and Knight, E. (2015), "Digital badges in education", *Education and Information Technologies*, Vol. 20 No. 2, pp. 403-410.

Goffman, E. (1959), *The Presentation of Self in Everyday Life*, Doubleday, New York, NY.

Grant, S. (2016), *Promising Practices of Open Credentials: Five Years of Progress*, Mozilla Foundation, Mountain View, CA.

Hagedorn, L.S. and Purnamasari, A.V. (2012), "A realistic look at STEM and the role of community colleges", *Community Colleges*, Vol. 40 No. 2, pp. 145-164.

Hickey, D. and Schenke, K. (2018), "Digital badges and reward structures", *The Cambridge Handbook of Motivation*, Cambridge University Press, New York, NY.

Hickey, D.T., Willis, J. and Quick, J. (2015), *Where Badges Work Better*, *EDUCAUSE Learning Initiative ELI*, available at: https://library.educause.edu/resources/2015/6/where-badges-work-better

Hickey, D.T., Uttamchandani, S. and Chartrand, G. (2018), "Competencies in context: new approaches to capturing, recognizing, and endorsing learning", in Bishop, M.J., Boling, E., Elen, J. and Svila, V. (Eds) *Handbook of Research in Educational Communications and Technology*, Springer, New York, NY.

Holland, D. and Lave, J. (2009), "Social practice theory and the historical production of persons", *International Journal of Human Activity Theory*, Vol. 2, pp. 1-15.

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K. and Watkins, S.C. (2013), *Connected Learning: An Agenda for Research and Design*, BookBaby, OR.

Klein, E. and Davis, K. (2016). "Designing digital badges for an informal STEM learning environment", in Muilenburg, L.Y. and Berge, Z.L. (Eds), *Digital Badges in Education: Trends, Issues, and Cases*, Routledge, New York, pp. 145-155.

Landis, J.R. and Koch, G.G. (1977), "The measurement of observer agreement for categorical data", *Biometrics*, Vol. 33 No. 1, pp. 159-174.

Leonhardt, D. (2017), "Lost Einsteins: the innovations we're missing", *The New York Times*, 4 December, available at: www.nytimes.com/2017/12/03/opinion/lost-einsteins-innovation-inequality.html

Plass, J. and Homer, B.D. (2015), "Good badges, evil badges? An empirical inquiry into the impact of digital badge design on goal orientation and learning", Report on 2013-2014 HASTAC Digital Media and Learning Research Grant Competition.

Renninger, K.A. (2009), "Interest and identity development in instruction: an inductive model", *Educational Psychologist*, Vol. 44 No. 2, pp. 105-118.

Restivo, M. and Van De Rijt, A. (2012), "Experimental study of informal rewards in peer production", *PloS One*, Vol. 7 No. 3, p. e34358.

Riconscente, M.M., Kamarainen, A. and Honey, M. (2013), *STEM Badges: Current Terrain and the Road Ahead*, New York Hall of Science, New York, NY, available at: http://badgesnysci.files.wordpress.com/2013/08/nsf_stembadges_final_report.pdf

Roy, S. and Clark, D. (2018), "Digital badges, do they live up to the hype?", *British Journal of Educational Technology*, available at: https://doi.org/10.1111/bjet.12709

Savolainen, R. (2009), "Small world and information grounds as contexts of information seeking and sharing", *Library and Information Science Research*, Vol. 31 No. 1, pp. 38-45.

Smagorinsky, P. (2008), "The method section as conceptual epicenter in constructing social science research reports", *Written Communication*, Vol. 25 No. 3, pp. 389-411.

Spaulding, S. and Johnson, M. (2016), *Realizing Employment Goals for Youth through Digital Badges*, Urban Institute, available at: www.urban.org/sites/default/files/publication/80241/2000772-realizing-employment-goals-for-youth-through-digital-badges-lessons-and-opportunities-from-workforce-development.pdf

Star, S.L. and Griesemer, J.R. (1989), "Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907e39", *Social Studies of Science (Sage)*, Vol. 19 No. 3, p. 387e420.

Tai, R.H., Liu, C.Q., Maltese, A.V. and Fan, X. (2006), "Planning early for careers in science", *Science*, Vol. 312 No. 5777, pp. 1143-1144.

Turkle, S. (2007), *Evocative Objects: Things we Think with*, MIT Press, London.

Tyson, W. (2011), "Modeling engineering degree attainment using high school and college physics and calculus course taking and achievement", *Journal of Engineering Education*, Vol. 100 No. 4, pp. 760-777.

Tyson, W. and Roksa, J. (2016), "How schools structure opportunity: the role of curriculum and placement in math attainment", *Research in Social Stratification and Mobility*, Vol. 44, pp. 124-135.

Wyn, J., Cuervo, H., Crofts, J. and Woodman, D. (2017), "Gendered transitions from education to work: the mysterious relationship between the fields of education and work", *Journal of Sociology*, Vol. 53 No. 2, pp. 492-506.

Further reading

Hickey, D.T., Otto, N., Itow, R., Schenke, K., Tran, C. and Chow, C. (2014), *Badges Design Principles Documentation Project (Interim Report)*, Center for Research on Learning and Technology, IN University, Bloomington.

Corresponding author

Caroline R. Pitt can be contacted at: pittc@uw.edu