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ORIGINAL PAPER

Guardrails to Constructing Learning: the Potential of Open Microcredentials to Support Inquiry-Based Learning

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Abstract
Inquiry-based learning has been growing in popularity, but the ill-structured nature of complex problem-solving still has challenges related to how to ensure students learn the content and how to provide feedback. This paper addresses this gap by exploring how open microcredentials can support open-ended learning by providing "guardrails" that simultaneously honor the openness of student inquiry while addressing these challenges. This manuscript begins by exploring the theoretical tenents of IBI and the importance of self-directed learning in ill-structured problem-solving. We then discuss the challenges documented in the literature and how microcredentials could address some of the implementation issues described in the literature.

Keywords Inquiry-based learning · Problem-based learning · Constructivist learning · Constructivism · Microcredentials · Open badges

Theorists argue that problem-solving is an increasingly important skillset in the information age (Glazewski and Hmelo-Silver 2018; Greiff et al. 2014; van Laar et al. 2017). Indeed, many problems in various domains are ill-structured; that is, the problems lack a clear solution or parameters for solving the case (Jonassen 1997, 2011; Park and Ertmer 2008). Solving these types of problems requires additional skillsets such as argumentation (Ju and Choi 2017), question-generation (Otero and Graesser 2001) and decision-making (Oh et al. 2018; Wilder 2015). In contrast with more lecture-based approaches, it is argued that instructional methods are needed that prepare learners for the types of problems they will encounter in practice.

Because of this, educators advocate teaching students with methods that require these skills. One of the most popular methods, inquiry-based instruction (IBI), "emphasizes open investigations of authentic problem scenarios in a student-centered and collaborative learning classroom context" (Ku et al. 2014, page 253) IBI approaches are beneficial for a number of reasons. For example, the contextualized nature of the problem allows learners to understand the relevancy of the concepts (Hod and Sagy 2019; Lazonder and Harmsen 2016). The open-ended affordances of IBI also allow students to take more ownership of their learning, which supports engagement in the problem-solving process (Capps and Crawford 2013). The strategy thus supports higher order learning skills, such as goal-directed behavior, causal reasoning (Eseryel et al. 2013; Giabbanelli and Tawfik 2019), and decision making (Oh et al. 2018; Wilder 2015) as they engage in meaning making of the connected concepts within the problem space. Hence, this strategy is especially conducive for schema formation (Peltier and Vannest 2017) and conceptual change (Loyens et al. 2015). Additional research shows that the authentic nature of the problem encourages other areas of learning, such as motivation (Wijnia et al. 2011/4) and self-efficacy (Brown et al. 2013). Finally, the contextualized and open-ended nature of the problem affords transfer for when similar problems are encountered (Luo et al. 2018; Rees Lewis et al. 2019).

However, despite the theoretical benefits of IBI, critics have pointed out inherent challenges to using this strategy.

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The first challenge is that since novices have little domain knowledge, it is difficult to provide them with authentic problem scenarios that they can solve. In short the dilemma facing IBI teachers is this: do they allow students to construct, through struggle, their own learning paths, or give them guidance so they can solve the problem adequately? And if guidance is provided, does it negate the benefits of inquiry-focused instruction? And if guidance is not provided, leaving the inquiry open-ended, will class time become overly focused on students gathering basic information to create their own scaffolds, leaving precious little time for adequately learning more important content and actually solving the ill-structured problems? (Reilly et al. 2019; Yuriev et al. 2017)).

The second challenge to using IBL is related to assessment. If ill-structured problems contain no prescribed answer, educators must instead assess based on the viability and justification of the proposed solution (Chian et al. 2019; Ju and Choi 2017), focusing on the students' causal reasoning, decision-making, and overall synthesis of their argumentation. Recent studies show that this process is time consuming and often impractical for educators (Tamim and Grant 2013), which contributes to teachers' reversion back to more didactic forms of teaching. However, if students are not provided timely feedback about how they are progressing, this leads to decreased learning outcomes (Wijnen et al. 2017). This is especially true for demanding open-ended cases posed in IBI (Baars et al. 2018).

One potential solution to both these two dilemmas of (1) scaffolding open-ended and lightly guided learning and (2) providing evaluative feedback, might be to use open microcredentials. A recent technology of the last decade, open microcredentials are credentials awarded for smaller amounts of learning, typically the acquisition of a single skill, demonstration of an accomplishment, or mastery over a single domain of knowledge. Because they support microlearning, they can be a motivating method to scaffold student learning of skills and domain knowledge. Additionally, microcredentials are typically designed to be self-contained microcourses, allowing students to "catch up" in areas where they may be weak. In addition, digital microcredentials are data-rich, meaning they can contain a wide variety of information about what the learner accomplished, including rubrics and criteria for earning the credential and endorsements from people who observed them. These affordances can provide powerful support for assessment and feedback of the student. Recently some research (Zheng et al. 2019; West et al. 2020) suggests that implementing microcredentials in education can support greater student self-regulation. If this is true, they may provide an intriguing bridge of the "theory to reality gap" that is often cited in the IBI literature.

However, to date there has been little discourse about the practical application of microcredentials to IBI. This paper therefore seeks to address this gap by exploring how open microcredentials can support open-ended learning by providing "guardrails" that simultaneously honor the openness of student inquiry while also (1) scaffolding the learning of the knowledge domain and (2) increasing the level of feedback provided to students. This manuscript begins by exploring the theoretical tenents of IBI and the importance of self-directed learning in ill-structured problem-solving. We then discuss the challenges documented in the literature and how microcredentials could address some of the implementation issues described in the literature.

Review of Research on Inquiry-Based Learning

Theorists have long argued that instruction should provide learners an opportunity to construct their own knowledge (Ertmer et al. 2012; Hmelo-Silver et al. 2007; Jonassen 1997). Although information dissemination approaches to learning provide an opportunity for learners to align new information with their prior knowledge, these approaches are inherently limited (Kolodner 1992) because lecture-based approaches can be devoid of context where learners fail to understand a concept's relevancy to domain practice (Brown et al. 1989). Thus, information dissemination approaches are not typically conducive for robust schema formation or long-term retention of concepts (Eseryel et al. 2013; Ifenthaler et al. 2011).

To better support learning, many have advocated instead for a more student-centered approach that focuses on problem-solving. From a learning perspective, Jonassen (1997) argued that as learners solve new problems, they are able to understand how to connect ideas during various stages, including problem representation and solution generation. In contrast to the decentralized approach, the ill-structured problems presented in IBI allow learners to understand how key concepts instantiate within a domain, which supports knowledge transfer (Schank 1999; Tawfik and Kolodner 2016; Woolley et al. 2019). Finally, others argue there is an affective element of engagement and motivation for learners as they encounter and resolve ill-structured problems (Brown et al. 2013; Dunlap 2005; Wijnia et al. 2011/4). Indeed, various comprehensive reviews document how inquiry-based instruction produces greater learning outcomes when compared with information dissemination approaches—when properly scaffolded (Belland et al. 2017; Lazonder and Harmsen 2016; Walker and Leary 2009).

Despite these benefits, the shift in instructional strategy includes challenges, especially in self-directed learning and assessment. In terms of the former, critics argue that the ill-structured nature of IBI presents problems beyond the complexity that novices can handle (Kirschner et al. 2006). While information dissemination approaches provide a specific set of content for students to interact with, IBI requires learners to engage in open-ended information gathering as they simultaneously understand the latent elements of a case. Learners must not only search and find the right resources, they must generate a mental model based on their shifting information of the case (Glazewski and Hmelo-Silver 2018). They must then use the information to generate and justify a viable solution in light of the constraints and perspectives inherent within the problem (Ju and Choi 2017). Indeed, studies show that this can be overwhelming for students as they try to demarcate the problem space and later to generate a solution given their newly acquired information (Ertmer and Koehler 2018).

Another challenge related to IBI includes assessment. While the self-directed learning may be challenging from a student's perspective, the open-ended nature of ill-structured problems suggests that multiple solutions may be presented to solve a given problem. The viability of the problem is equally as important as the reasoning processes, evidence presented, and other areas (Graesser et al. 2005; Jonassen 1997; Reilly et al. 2019). Given that there is no prescribed "right" answer, learning artifacts include those that represent more divergent ways of thinking, including concept maps (Olney et al. 2012), argumentation (Iordanou et al. 2019; Von Aufschnaiter et al. 2008). However, studies show that learners require timely feedback to resolve misconceptions, especially for complex problems (Netcoh and Bishop 2017; Wijnia et al. 2016). If there is no" 'right way'" to solve a problem, this presents a practical challenge from a teaching perspective that mitigates the potential effectiveness of IBI within classroom settings.

Open Microcredentials in Support of Open-Ended Learning

This tension between providing structure for learners while allowing self-regulation may be partly due to the types of credentials and assessments we provide. The credential that a learner receives to recognize their learning may seem like an insignificant byproduct of the educational system. However, this credential is the main communication mechanism about what the learner knows and can do. It is also the major motivation to the student, and a communication medium for explaining expectations prior to learning. It is thus valuable to ask whether a change in credentials may help support a change in pedagogy towards more inquiry-based learning.

Traditionally, educational credentials have been *macro*, issued at the end of a larger program of study, and *institution-directed*, in that they represent the expectations the institution has for the student, and the criteria they expect the student to meet. In this way, traditional credentials seem at odds with student agency, self-regulation, and self-actualization in learning. But is there an alternative?

Open microcredentials are a recent development and major shift in how we think about recognizing student learning. Initially developed by the Mozilla Foundation in 2011, open microcredentials rely on a common technical standard, such as the Open Badge Infrastructure, currently maintained by IMS Global (https://www.imsglobal.org/activity/digital-badges). When a microcredentialing system uses this technical standard, then the credentials issued can be imported into any receiving system, or "backpack." In practice, this allows a learner to collect credentials and assessment data from more than one institution and organize them within their own online portfolio. This is a radical disruption of the traditional educational model, where credentials were primarily earned at one institution, such as a university. With open microcredentials, any learning, occurring anywhere, taught by anyone, could be recognized.

The "micro" size of open badges (typically representing achievements much smaller than a multi-year degree) and the data portability create many possibilities for microcredentials to be earned in unique ways. In fact, since their introduction in 2011, over 25 million open badge credentials have been issued (personal communication to the author by IMS Global on November 15, 2019). However, the reality has been that open microcredentials have been primarily used to represent technical and process skills—those that are more easily counted and measured. This has created an opportunity for instructional designers to explore how open microcredentials can support learning that is more conducive toward constructivist pedagogies.

How Microcredentials Can Support Inquiry-Based Instruction

As noted earlier, the open-ended nature of IBI includes both opportunities and challenges. In terms of the former, a more open approach to education allows learners to take ownership of their learning and engage in more complex reasoning (Capps and Crawford 2013; Hung 2015; Loyens and Rikers 2011). However, the open-ended nature of problem-solving in IBI makes it hard to definitively assess cognitive and affective learning outcomes that IBI purports to increase (Giabbanelli and Tawfik 2019; Chian et al. 2019; Eseryel et al. 2013). This makes it difficult for educators to provide timely and accurate feedback that is important for students as they construct their knowledge. One of the core benefits we have seen from implementing open microcredentials has been that they cause us to think differently about our teaching and assessment strategies. As it relates to problem-solving, microcredentials may uniquely address some of the challenges identified in the literature, namely the challenge of supporting self-directed learning and assessment. In terms of the former, microcredentials can be used to establish the necessary background knowledge and pathways. Alternatively, microcredentials afford unique opportunities for assessment because of their flexibility (criteria, evidence) and even ability for learners to claim, rather than receive, credit. Below we expound on each of these points.

Microcredentials Can Facilitate Learning Requisite Background Knowledge In inquiry-based instruction, learners are given an ill-structured case as a way to catalyze their learning. However, one of the criticisms is that novices lack the prior experience and foundational knowledge/skills needed to solve the open-ended case. For example, asking students to solve authentic problems in the community related to public health would require previous knowledge about public policy and medicine. A major pedagogical challenge is how to “limit” the problem space of a case so that it is manageable for novices.

Microcredentials can be used as a way to address this challenge by outlining the foundational knowledge and skills that students need to know before working on a problem or launching into an inquiry. In these situations, students must earn the prerequisite microcredential to prove readiness for the problem solving activity, and support could be given in class to earn the prerequisite microcredentials or they could earn them outside of class. This could also provide a boost in self-efficacy to students that they are ready to engage in the authentic problem-solving task. In the example of one of the Randall et al. (2013), technology skills microcredentials served as prerequisites before students began a project-oriented class. Similarly, Newby, Wright, Besser, and Beese (2016a and b) described the use of educational technology badges at Purdue for teaching competencies such as digital literacies. In their case, the microcredentials required open-ended problem-solving to solve suggested educational problems. However they used microcredentials to define prerequisite technology skills that students required in order to complete the problem solving exercises (see Fig. 1). In another case, Learning Inspired by FedEx (LiFE), employees were given the chance to take college preparatory courses in order to gain admission into a degree program. The course was structured with prerequisite microcredentials for academic success, like time management and study skills, placed before complex issues like career planning and development (see Fig. 2).

Additionally, students learn in many places and communities, including families, school, friends, online networks, employment, and community groups. Open microcredentials can recognize these various types of learning and remove the artificial barriers between formal and informal learning. Thus, it is possible that these microcredentials representing key prerequisite information could be learned and earned in the community, on the job, or at other institutions. This can make it more possible for course instructors to mentor inquiry and problem solving, while allowing students to develop skills and domain knowledge in multiple ways that are conducive for knowledge construction.

Microcredentials Can Establish Flexible Criteria and Receive Flexible Evidence Inquiry-based instruction argues that the process of learning is as valuable as the final artifact—at least to the students and their learning. While the student solutions may differ, IBI contends that all learners engage in complex reasoning skills such as causal reasoning, questioning, decision-making, and argumentation. A key affordance of microcredentials is that there can be flexibility in how evidence is represented. Oftentimes, a microcredential’s criteria can include that the learner demonstrate reflective practice, or show evidence of their decision-making. Learners can then flexibly collect evidence that best argues for their successful demonstration of these skills. In addition, microcredentials can require reflection from the earner, where they can again shed light on their learning process. Therefore, microcredentials can be used as a way to communicate difficult to measure learning outcomes and provide incremental feedback about the problem-solving process.

Theorists assert that badges have the potential to assess “experiences that so far have not been valued/recognized” (Jovanovic and Devedzic 2014, page 60). Empirical studies

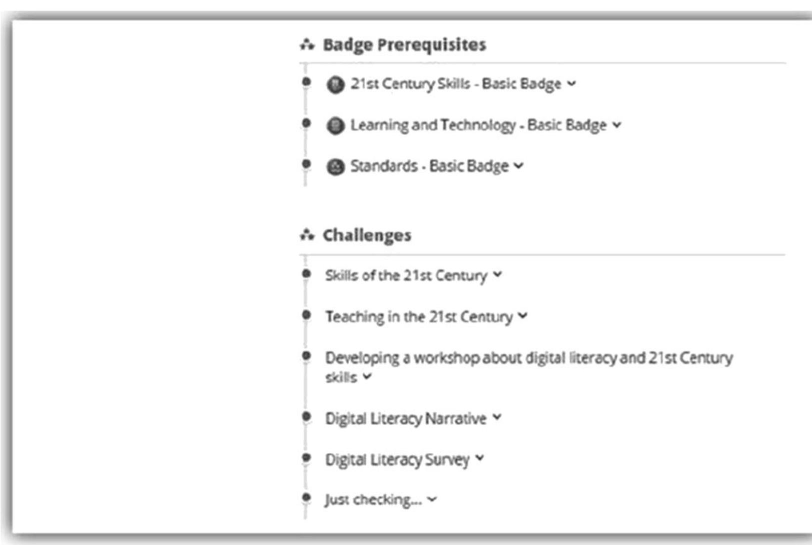

Fig. 1 Prerequisite badges in “Being Digitally Literate in the 21st Century” course from Purdue University

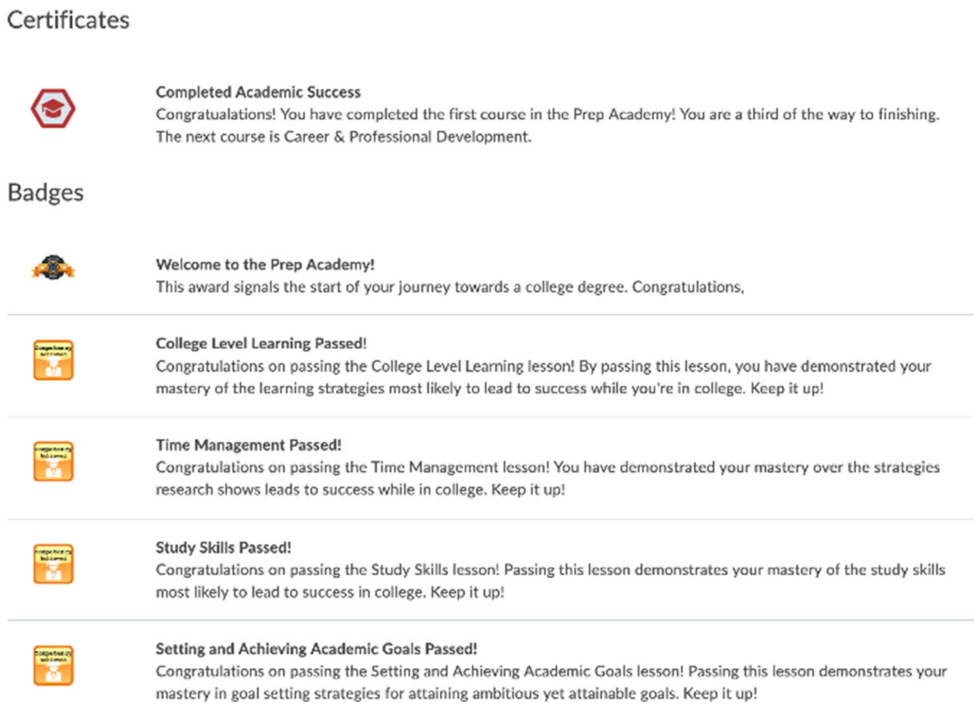

Fig. 2 Prerequisite academic skill badges for the FedEx LiFE program

show that badges have been issued to reward alternative forms of learning, especially as it relates to affective outcomes of motivation (Reid et al. 2015; Kyewski and Krämer 2018; Iwata et al. 2017; Salmon et al. 2015). Indeed, these diverse data points are made possible because a microcredential serves as a mini portfolio that can receive as much data as one can think to add. There is, conceivably, no limit to what data could be represented in a digital credential, which is different from paper-based credentials. This flexibility requires students to make an argument that their evidence meets the criteria, and in this process they again demonstrate open-ended, inquiry-based skills as they make this argument. It also allows for earners to show their uniqueness. In Utah, a new microcredentialing initiative, for example, has set standards for teacher professional learning in order for the credentials to be officially recognized—but ***how*** teachers provide evidence for those skills can vary. Teachers need to provide both direct and indirect evidence, but that evidence could include student scores/work, videos of their teaching, lesson materials, reflections, or observations from peers/leaders (see https://www.uen.org/utahdigitalbadges/).

In another example, Stansberry and Haselwood (2017) described a master's course introducing learners to the use of games and simulations in education. Microcredentials were used to identify different skills learners needed or achieved in learning quests. Some of these credentials were automatically issued when learners accomplished tasks or answered questions in the course, while others were issued by the instructor for skills such as critical thinking, creativity, problem solving, collaborative learning, personal growth, expansion of ideas, and leadership. These microcredentials denoted to learners that the skills they were developing were being noticed and rewarded; and the microcredentials were flexible enough to represent both content learning as well as more process learning skills for this ill-structured problem.

Credential Pathways Can Provide Learners Choices As learners engage in their problem-solving, IBI allows learners to develop different solutions based on their meaning-making from the evidence and ensuing rationale. Whereas the didactic approach prescribes a single answer, IBI learners generate their own solutions and choose among many options to address the challenge. However, research shows that learners often have difficulty within the solution generation stage with too many available options (Kapur 2018; Schmidt et al. 2011), which can be overwhelming. While students appreciate self-regulation, guardrails are needed to limit the choices so it does not create a paradox of choice for them (Schwartz 2004).

Badges are often used in gamified learning environments to suggest the pathways learners should take as they direct their learning (Abramovich et al. 2013; Kyewski and Krämer 2018; Fanshawe et al. 2020). Badges can address some of the issues described in IBI by providing the structure needed to support the self-direction, but without overscripting the learning. In one recent study, noted that "badges within a badge family or hierarchy may fit together as a collection of related badges". Similarly, a study by Cheng and colleagues (2019) found that badges served as a visual representation of one's goals in a class, which supported their self-regulated learning.

Additional studies have explored the role of badges in supporting problem-solving and self-regulated learning in diverse ways. In 2018, Badgr announced *Pathways*, the technological solution to a long-discussed potential feature of open badges (Skipper 2018). Pathways allows an institution or teacher to create a learning path, sometimes called a *stack,* defined by core skills or competencies, and then identify which microcredentials fulfill requirements in the pathway. This makes the microcredentials stackable, as they can be combed to complete an entire pathway of learning, representing learner growth over time. Often, higher-order credentials can be automatically issued when the subordinate credentials are all earned (see Clements et al. 2020). A key feature of pathways is that multiple credential options can fulfill a requirement in the path. So instead of telling students they must do X, an instructor can allow self-direction by telling them they can do X, Y, or Z to fulfill requirement #1. In line with the open-ended nature of IBI, instructors in these scenarios can be satisfied that students have learned important skills that meet course learning outcomes, but students have the freedom to pick the most relevant and interesting skills or tasks for them.

As an example, in Randall et al. (2013) we described a system for educational technology microcredentials where students had multiple options of which technologies they mastered to fulfill various categories and learning objectives. Figure 3 illustrates four different pathways to achieving the Educational Technology badge. Learners can select three lower level badges or one project level badge to meet the course requirements. Similarly, Gamrat, Zimmerman, Dudek and Peck (2014) described a program for inservice STEM teachers that offered 63 different microcredentials. Teachers selected from this suite of learning options to create their own customized learning paths and professional development plans. As another example, Idaho Skillstack is an effort to provide microcredentials to career and technical education students in Idaho. For each career track, a certificate can be earned by receiving a stack of microcredentials. Each microcredential outlines the prerequisites needed, the criteria for earning the credential, and which institutions are able to issue the credential (see https://skillstack.idaho.gov/, and Fig. 4).

Learners Can Claim, Rather than Be Issued, Credit An important aspect of inquiry-based instruction is the learner's ability to self-direct their learning. However, education is not designed to allow for true self-direction. Traditionally in education, an experienced teacher or institution establishes the criteria for learning and the requirements for demonstrating mastery. These are communicated to the learner, who then must provide evidence of meeting these requirements before being issued a credential by the institution. Thus, despite the focus on students driving the learning, it is still typically the instructors that determine when a learner has finished, or accomplished the tasks.

However, what if learning recognition worked differently? What if learners were recognized as the most knowledgeable about their own learning, rather than the "experts?" What if learners established their own criteria for progress, and then

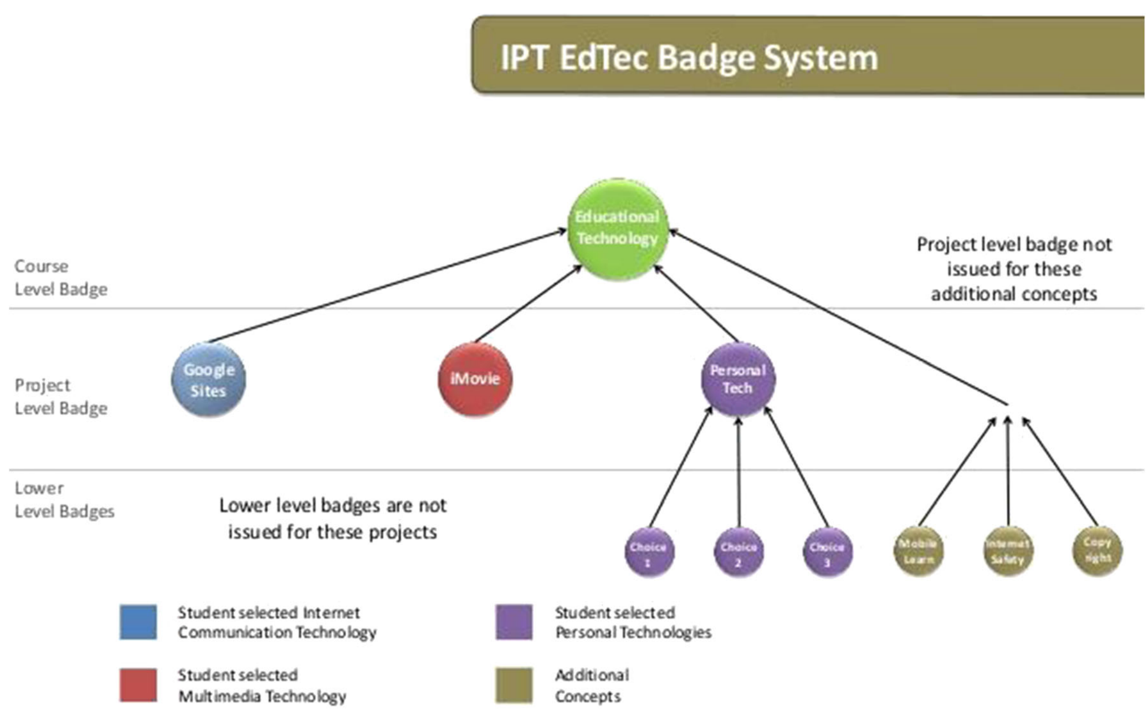

Fig. 3 Description of badge pathways for teachers completing educational technology projects from Randall et al. (2013)

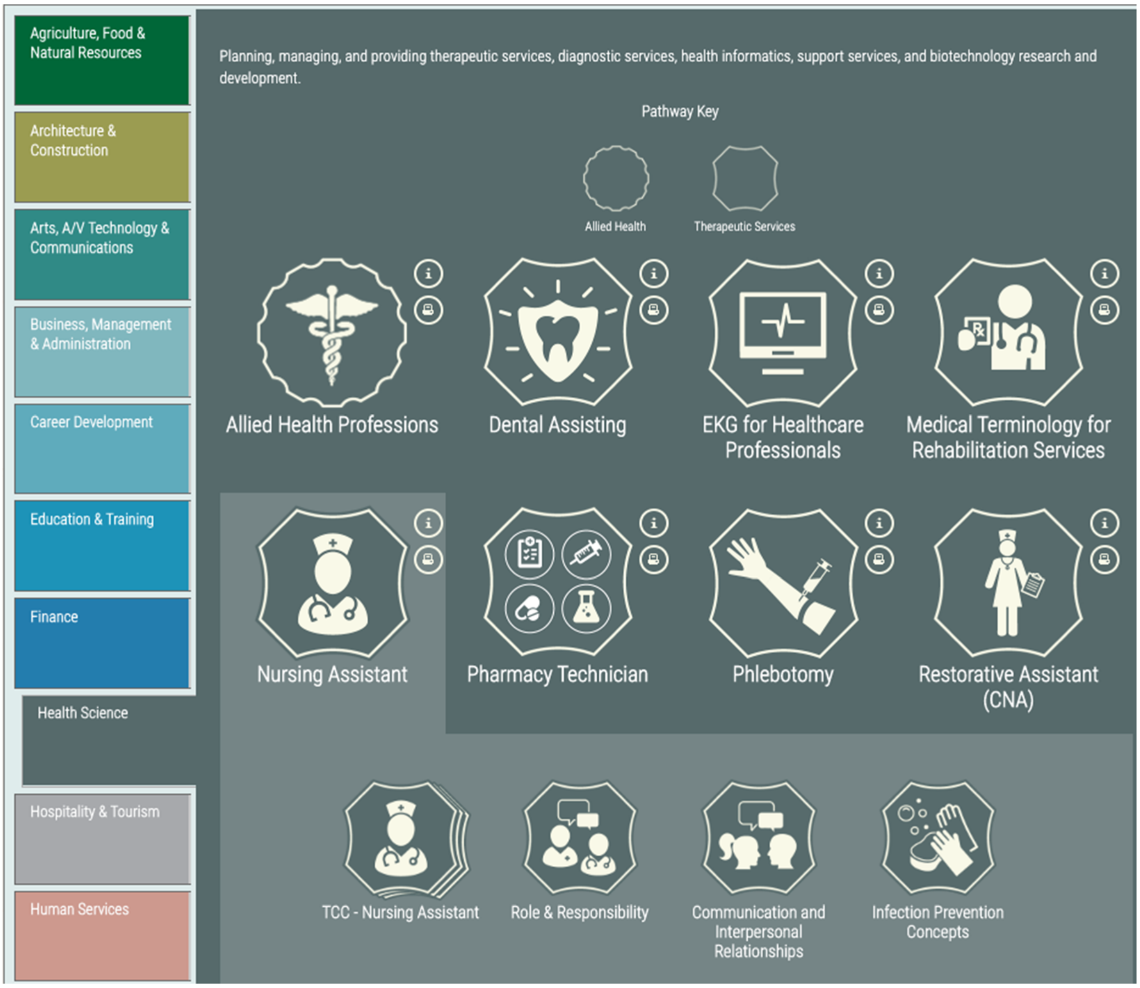

Fig. 4 Example of CTE skill credentials stacking into a career certificate as part of Idaho Skillstack, available at https://skillstack.idaho.gov/

claimed credentials as they met their goals? This approach empowers learners to know what skills they have and what they need, and provides validation for the skills they know they have acquired. This can create a new perspective on how we come to trust credentials and recognize authentic learning.

These ideas are driving a new development in the badging community: the concept of user-claimed badges and *open recognition*. Similarly, institutions are looking to badges as a means to recognize mastery from experience and other credentials (Devedžić and Jovanović 2015; Lemoine and Richardson 2015). The lead author accidentally realized the power of learner-generated credentials as part of our own work developing Badgeschool educational technology microcredentials for preservice teachers (Randall et al. 2019). In this project, our primary goal was to provide a wide variety of microcredentials that preservice teachers could earn. Each microcredential represented an educational technology or technology integration skill we felt could be valuable in their teaching. However, developing this large suite of microcredentials, particularly as technologies continued to evolve, was challenging. In addition, we did not have sufficient content knowledge to create the most useful microcredentials for every discipline.

As an experiment, we began allowing students to create their own open microcredentials. If a student wanted to learn a skill that we did not have an open microcredential for, they would research the skill, draft their own list of criteria, and provide examples of evidence for meeting that criteria. They then told the instructor when they felt they had met the criteria that they themselves had established. We had the responsibility to give final approval for these microcredentials, but rarely if ever denied a microcredential to a student who had created their own. We do believe, though, that critical to the students' successful development of a credential was our modeling of what high quality projects and assessments should like through our other available credentials in Badgeschool, along with our scaffolding of the students through the credential-creation process (see Randall et al. 2019, for descriptions about this process).

Surprisingly, when we had educational experts review the rubrics for our open microcredentials, they found that the student-created rubrics were stronger! While we were experts in the general sense, and we believe it was critical that we provided our guidance and modeling of what strong, acceptable projects and project assessment should look, the students were experts in their *specific case.* They understood best their own learning goals, and were highly motivated to show mastery in the skill they cared about. Conceding some of this expert authority to the learner in reality made the learning more powerful, and the burden of creating and issuing open badges much more sustainable.

Stanberry and Haselwood (2017) described a similar learning process in their example, as learners could receive the Questbuilder badge by earning 700 experience points and then designing their own quest for the class. Though the instructor had to give them the credential, students claimed the credential through the creation of their own quest on a topic they deemed important for the class to know about. Achieving the Questbuilder badge was not forced upon the learners but was rather an achievement that the learner claimed through completing the optional task.

We have not been the only badge practitioners to openly question the wisdom of only allowing microcredentials to be created and issued by "professionals." The Open Recognition Alliance, an international community, is openly advocating for revising how we think about recognizing student learning and how we establish "trust" in credentials. See more of their work at https://www.openrecognition.org/.

Conclusions and Future Directions

In an increasingly complex world and working economy, our students need more than just conceptual understanding—they need practice problem solving and engaging in open-ended inquiry practices. In contrast to information dissemination approaches that dictate to learners what they need to know, inquiry-based instructional strategies focused on problem solving encourage learners to solve cases that are representative of the types of problems that practitioners encounter (Hung, 2015; Savery, 2006). Through IBI, learners navigate the problem space to identify key concepts they must explore and work with their peers to generate solutions to the problems. Learners then share ideas (Rillero & Camposeco, 2018) and negotiate new knowledge based on their understanding of the case (Ertmer and Koehler 2018).

Despite the many positive outcomes documented in the research for IBI, researchers have identified unique challenges from an implementation perspective, especially as it relates to supporting self-directed learning (Kim et al. 2019; Wilder 2015) and assessment for ill-structured problems (Tamim and Grant 2013; Wijnen et al. 2017). In short, how can instructors manage this difficult balance between enough structure to provide support to novices, while providing enough freedom for open-ended learning and problem solving? In addition, how can learners document their learning in a constructivist learning space, and how can instructors provide feedback on their progress?

In this paper we have suggested that one possible technological solution to these challenges could be open microcredentials. These microcredentials can support IBI by (1) facilitating how learners gain prerequisite knowledge for problem solving, (2) establishing flexible criteria for learning and accepting flexible forms of evidence of that learning, (3) utilizing learning pathways to provide pre-approved choices for self-directed learning, and (4) creating new opportunities for learning recognition, including empowering learners to describe and claim credit for their own learning.

In making these suggestions, we recognize there is very little evidence to support these new ideas—this is because there is very little research or design precedent in general for open microcredentials. Many questions exist about these potential applications for IBI microcredentials. This provides a powerful opportunity for scholars and designers in our field.

Implications for Research

Because the majority of current open microcredentials represent skill and basic knowledge acquisition within more content-driven instruction, there is a huge gap for researching how open microcredentials can support open-ended teaching practices. For example, can microcredentials provide enough scaffolding for students to self-learn prerequisite knowledge? What institutions and groups can be trusted to provide this prerequisite learning? Can learners truly organize their own learning and gather their own evidence of learning progress? Will utilizing microcredentials increase workload burdens for instructors, and will the feedback given to learners be easily understood? Can these credentials, especially when organized and claimed by learners, generate sufficient trust that the learners are truly ready for real-world problem solving?

In short, within an open microcredential infrastructure, there are potential research opportunities surrounding the following key groups:

1. Credential earners/students—How does the introduction of open microcredentials affect their learning, motivation, and engagement in inquiry and open-based learning?
2. Credential issuers—What benefits and costs are there for institutions in offering these microcredentials? Does it require additional resources? Does it dilute the brand (or expand the brand) of the institution to offer microcredentials alongside traditional degrees?
3. Credential interpreters/receivers—What do employers, graduate program admissions committees, and other entities who will *interpret* or try to understand these credentials think about them? Will they recognize the advanced

learning and career preparation that will come from inquiry-based learning microcredentials?

These are legitimate questions, and ones that merit strong consideration from researchers in our field.

Implications for Practitioners

In our field, we recognize design precedent as another powerful way of advancing knowledge in the field in addition to research. Simply put, we do not have very many written design case studies of institutions using microcredentials and reflecting on their lessons learned, and this is especially true for inquiry-based learning situations where the design precedent is practically non-existent. Even those institutions that have been implementing microcredentials have not left much of a reflective written trail to guide colleagues. We believe one of the best ways of advancing practice in this area would be for more teachers and departments to try out the concept of open-ended learning with microcredentials and then report and reflect on their practices and lessons learned. These can be published in journals that accept design cases, or made available via the Internet.

As yet, there is much we do not know about how effectively open microcredentials can be integrated into teaching practices. However, while pursuing a new model of credentialing could be disruptive to educational systems, we also believe the potential benefits warrant the careful study of these possibilities through both research and reflective design practice, and we encourage colleagues to explore this journey with us.

Compliance with Ethical Standards

Conflict of Interest The authors declare they have no potential conflicts of interest.

Research Involving Human Participants This article does not report research involving human and/or animal participants.

Informed Consent This article did not require informed consent as it is not reporting research.

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