An Online Badging System Supporting Educators' STEM Learning

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ABSTRACT
In this paper, we investigate how a digital badging system was used as part of an informal, not-for-credit professional development project. Teacher Learning Journeys was designed for personalized science learning for educators in K-12 schools, museums, universities, and teaching colleges through employing two levels of micro-credentials: lower achievement digital stamps and higher achievement digital badges. Researchers conducted a qualitative collective case study centered on 36 teachers; the primary data were records from learners' interactions within the digital badge system; secondary data came from a survey at the end of the experience and two interviews with 11 focal teachers. Findings suggest the following design principles: (a) two levels of assessment can support personalized learning, (b) mastery of learning can be demonstrated and assessed through reflective logs, (c) collaboration during and after badging activities can provide value to the learners, and (d) establishment of relevance of badging experiences can support the application of content outside the badging system.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: Computer uses in Education – *collaborative learning*

General Terms
Design, Human Factors

Keywords
Digital badges, Open Badges, Science Learning, STEM Education, Professional Development, Lifelong Learning, Learning Across Settings

1. DIGITAL BADGES IN EDUCATION
Digital badges have been proposed as tools that learners can use to support short-term through lifelong learning within and across various educational institutions [10, 11]. We define digital badges as online representations of learning experiences, which serve as micro-credentials that document learners' expertise and skills. While digital badges can be housed as online representations within private badging systems, they can also be shown on other websites to serve as visual representation of learners' experiences to outside audiences through Open Badges standards, an initiative of the Mozilla Foundation. When badges are considered as a communicative tool, researchers have been renaming digital badges as Open Badges [13]. When shown to external audiences, digital badges can contain metadata viewable by others (i.e., the issuer, certifying agency, activity description, expertise the badge signifies, and evaluation criteria). Thus, badges offer transparency to the assessment of individuals' achievements and are available for scrutiny [10]. In this way, digital (or open) badges with their associated metadata are part of people's professional portfolios that document learning, skills, and experiences in an easy-to-share format. Open Badges and digital badges are terms used throughout the technology-enhanced learning field. Our system (described below) was designed to be Open-Badge compatible, but this functionality was not available for learners during the study period, so we use the term digital badges in this paper.

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Digital badges have been used in social media and online games in five key areas identified by Antin and Churchill [3]: (a) setting goals and providing feedback on goal achievement, (b) providing instruction about what activities are possible, (c) building a user's reputation based on interests, (d) serving as a status symbol and documenting achievements, and (e) showing affiliation with a community. As digital badges have been used increasingly in education, three of these five gaming categorizations from above have been conceptualized as important for use in learning environments: (a) rewarding and motivating achievements, (b) credentialing or recognizing learning (with badges serving as micro-assessments), and (c) acting as markers that learning has occurred for learners themselves, the learners' teachers or mentors, and the learners' peers [2, 13].

1.1 Research Findings on Badges within Educational Systems
While many types of educational institutions are adopting digital badges, empirical research studies (qualitative, quantitative, or design-based investigations) into how digital badges (and now Open Badges) support learning have only recently been published. Because the research is new, themes on the role of digital and Open Badges in education are emerging.

Through an analysis of 30 badging projects funded by the Badges for Badges for Lifelong Learning Competition (funded by the MacArthur Foundation) Hickey et al. [11] offer numerous design principles for recognizing, motivating, assessing, and studying learning with digital badges and within badging systems. Six of these design principles are related to our inquiry: (1) support learners to *set goals* related to the badging activities, (2) *map learning trajectory* through badge display pages and badging activity logs, (3) *promote collaboration* through the discussion of personal backgrounds and experience in the subject matter, (4) use hierarchy of badges or *leveled badge systems*, which suggests learners pick interlocked content and decide their level of assessment, (5) use *mastery learnin*g to focus on awarding badges to learners who reflected on their activity and described how they might implement it in the future—outside the badging system, and (6) *enhance the badges' validity with expert judgment*, which

asserts that master practitioners or other experts can be used to review the work of learners and to act as mentors.

In research with 51 middle school pupils (seventh and eighth grade) who were learning science, technology, engineering, and math (STEM), Abramovich, Schunn, and Higashi [1] investigated the interaction of badges with learners' prior knowledge and motivation. To accomplish their study, the team designed two types of digital badges: one was awarded for participation (without regard for learning outcomes) and the other was awarded for demonstrated mastery of STEM skills (as an assessment).

Abramovich et al. found that learners were motivated differentially by the badges. Participation-only badges were earned eventually by every student, and had little to no impact on learning and motivation. In the case of the skill-oriented badges, the more skill badges earned, the more those learners expected to be successful in mathematics. The authors concluded that learners who earned the least number of skill-oriented badges also had less expectation for STEM content learning success than those who earned more skill-oriented badges.

From their study, Abramovich et al. make two recommendations to the design of badging systems. First, they suggest that to maintain high levels of learner motivation badging system designers include few participation-only badges and have many skill-oriented digital badges available. Second, based on an analysis of survey data, Abramovich et al. suggest that provision of instructions on the criteria needed to earn a badge will also assist to keep motivation high.

While much of the research has occurred within STEM learning environments, not all badges are focused on STEM content. For instance, from their case study of badges to support self-regulation in an online STEM course, Cucchiara and colleagues [8] developed interrelated badges, in what they referred to as a "badge ecosystem," to incorporate technical and interpersonal (i.e., soft) skills. These nontechnical badges were important aspects of the holistic badge offering for this project.

1.2 Digital Badges as Pedagogical Tools

Within the broader landscape of technology-enhanced learning research, our research interests are aligned to badges as pedagogical tools. Our perspective is that badges can support learning and act as markers that learning has happened. The recognition that learning has happened is important not only for learners, but also for their teachers and mentors, and their peers in the same learning environment [2, 13]. In this way, we consider badges as pedagogical tools used by learners and their teachers and mentors to support informal learning.

Hickey et al. [11] have categorized the extant badging research, into various types. Given the Hickey et al. typology of badging research, our analysis falls into *research with badge*s and *research of badges* [11]. This means that we are considering how to improve the impact of badges in the learners' lives (i.e., research of badges), while we are also attending to the metadata within the badging system to improve the badging experiences (research with badges) [11]. Our research group has created a series of projects to investigate digital badges as a means for increasing learners' choices and decision making within and across informal, formal, and professional development activities. Research with badges and for badges refers to our intent to use badges to offer improvements for systemic impact such as offering a mechanism to support professional development needs.

Our project's overarching research goal is to examine learners' badge-earning pathways in order to refine learning theory about how the things that learners learn in one setting can be applied to another consequential setting via computer tools. For example, our team's prior work has examined the role of: digital photography in supporting learning across settings [20], mobile computers in supporting meaningful conversations about science where families' prior experiences are made relevant to new experiences in informal institutions, [21] and technologically-enhanced web 2.0 tools in supporting connections from community to school [22]. Our project here builds on our team's prior work of designing for learning across settings. In addition, within this badging project, we seek to develop design principles applicable to improving the educational programming related to badges and the badging system designs of badge issuers.

In this analysis, we focus on investigating the following research question: How do learners interact with elements of a digital badging system including the goal statements, logs, materials submitted to earn a stamp or badge, and their mentor? We answer this question through a tiered case study analysis of 36 schoolteachers and with the in-depth analysis of 11 of the 36 teachers. Of these 11 focal teachers, we present a *thick description* of two teachers' experiences—one teacher who represented a typical badge system user and one teacher who represented an intense user of badging.

2. TEACHER LEARNING JOURNEYS (TLJ) BADGING SYSTEM

TLJ was created to support teacher professional development (PD) in STEM subjects for K-12 education in the United States. Teachers accessed the TLJ system to engage in STEM learning at their own pace and to meet their own identified needs and a level of depth that reflected the needs of the pupils in their classrooms.

2.1 TLJ's Goal to Support STEM Learning

In the first year of the TLJ system's operation that is presented here, educational badging options included 54 activities related to three areas of science and engineering: solar system (19 badging activities), weather and climate (20 badging activities), and engineering (16 badging activities). The teachers earned badges by reflecting on activities that they participated in; these badging activities covered a wide-range of PD activities. PD activities used in our badging program included synchronous webinars, asynchronous discussion boards, educational media and texts, archived online presentations by scientists, engineers, and education experts. Figure 1 shows one of the 20 badging activities in the Weather & Climate library.

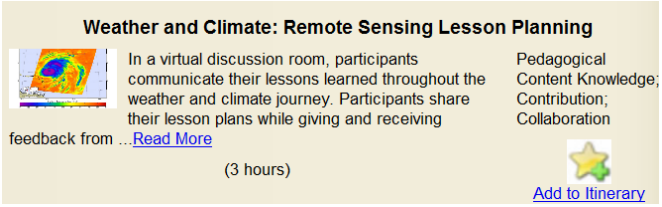

Figure 1. The Remote Sensing badging activity within the weather and climate topic area.

2.2 Features of the Badging System

Teachers were introduced to the system through an instructional video created by the principal investigator of the project. This video elaborated on badges and each of the functions available. Also, teachers were invited to use as many of the available badging PD resources as they wanted.

The TLJ badging system was developed utilizing a travel metaphor. TLJ helped teachers to set their unique learning goals for their badging journey, find relevant badging activities to support their goals, compose a log of their experience for the activity that could be submitted to earn badges, receive feedback from an expert as they continued their journey, and store all of their badges (accomplishments) in display pages styled to be similar to that of the stamp inside of a passport.

A teacher started their learning journey by creating a TLJ account and writing a goal statement. While optional, the goal statement was used to meet goal-setting needs by helping the teacher to begin to articulate a learning pathway [11]. Next, the teacher could review all 54 PD badging activities or search through them by topic or grade range and decide which to add initially to their itinerary. Only the teacher and the research team could access each itinerary. In this section, the teacher could review the badging activities they wanted to accomplish or remove badging activities they no longer wanted to complete.

The teacher then could initiate any PD badging activity from their itinerary by attending a webinar or engaging in other educational activities. In TLJ, no credit was available just for participation; the ideas had to be applied to the teacher's educational setting. The teacher then chose to submit their materials to earn a stamp or a badge, as described in Section 2.3. A National Aeronautics and Space Administration (NASA) education expert was assigned as a mentor to the teacher based on the content area of the badge. The mentor provided written feedback to the teacher, which resulted in the (a) earning of a badge or a stamp or (b) additional activities to be completed. The feedback was stored in the system as part of the metadata associated with their engagement with a particular activity and could be accessed by the teacher, the mentor, and the researchers. Then, the teacher's itinerary would change to show that the badge was earned.

After earning a badge or stamp, the teacher would have the option to anonymously fill out a survey on the activity, which gave the research and development team valuable feedback. The teacher would also be able to view the status of their badges and stamps in portfolio pages for the earned achievements. Additionally, any badges or stamps that were being reviewed by mentors were also displayed with the text *pending* superimposed on the badge image. The teacher could also review their work in the log section. This feature of TLJ acted as a blog-style page that captured each entry the teacher made for the activities completed as well as any additional evidence they uploaded for review by a mentor or that they wanted included in their badging portfolio.

2.3 Features of the TLJ Stamps and Badges

An important feature of the TLJ badges was that they were leveled [11]. Once teachers selected the PD badging activities from TLJ, they controlled their level of engagement with the topic by adjusting the type of micro-credential sought for learning ─ a TLJ stamp or TLJ badge. A TLJ stamp reflects the teacher's need for a more cursory engagement with and consequent assessment of an activity. The stamp is the lowest level badge. A TLJ badge is earned for a higher level of mastery, and shows a more in-depth engagement with not only the STEM concept but also with applying the STEM concepts to the teachers' professional settings. The TLJ badge is the highest-level badge, and for sake of clarity in the paper, we will only refer to the highest level of badges as badges; the lower level will be referred to as stamps.

To illustrate the difference between badges and stamps, the PD badging activity, Scale Models: The Earth-Moon System in the Solar System is a good example. This Scale Models activity has three options for teachers: (1) the entry-level activity is earning a TLJ stamp (Figure 2 left); teachers attend the webinar and write one brief reflective post, (2) a higher level of mastery means earning a TLJ badge (Figure 2 right), teachers also attend the webinar but they write a full lesson plan on incorporating the content into classroom activity, or (3), teachers can earn both the TLJ stamp and badge for this Scale Models activity by meeting both the stamp and badge criteria. To make the stamp and badges visually distinct, the stamp was given a design akin to a passport office rubber stamp and the badge an embroidered patch as shown in Figure 2.

Figure 2. A TLJ stamp (left) and a TLJ badge (right).

3. THEORETICAL FRAMEWORK

To support our analytical work, our theoretical framework considers bringing together the concept of cultural tools from sociocultural theory [18] with three dimensions of mobile learning [14] (i.e., authenticity, collaboration, and personalization). As such, we examine how badges and the badging system acted as cultural tools to mediate the teachers' learning in regard to authenticity to relevant STEM teaching and learning in K-12 schools, collaboration with other teachers and mentors, and personalization to their educational setting.

3.1 Cultural Tools to Mediate Learning

Vygotsky's [18] work in sociocultural theory maintains that learning requires people to use cultural tools with the help of experienced others. Cultural tools are artifacts such as physical objects, conceptual symbols (including language), and representations that people use within goal-directed actions [13]. For example, within studies of technology-enhanced learning, Cole [7] describes three kinds of artifacts that serve as cultural tools: (a) physical objects (e.g., a computer, calculator, or hammer), (b) representations and ways of acting, and (c) imagined artifacts (e.g., games and art). In this way, cultural tools are the set of resources available to members of a cultural group to mediate meaning-making. In our work, we consider how the badges and the badging system served as cultural tools to mediate STEM meaning-making for teachers along the dimensions of collaboration, authenticity and personalization, as described below.

3.2 Dimensions of Mobile Learning Environments

Our TLJ research and development was guided by a framework for mobile learning [8] because TLJ was intended for use by learners as they moved across social and technological settings—in their schools, homes, or communities accessed by desktops, smart phones, tablets, and other computers. While our prior work focused only on the personalization dimension of mobile learning

[9], this analysis focuses equally on authenticity (also referred to as relevance), collaboration, and personalization because when related to teacher PD, these three learning dimensions address the prior critiques of ineffective PD [5] and show what is possible through digital badging systems.

3.2.1 Authenticity

In the Kearney et al. model [14], authenticity is a mobile learning dimension comprised of two subcomponents: contextualization and situatedness. Contextualization is high when a learner is exposed to learning situations that are perceived to be realistic or relevant [4] to their personal or professional life. By making use of TLJ, teachers focus on the specific PD badging activities that are relevant to the topics and grade levels that they are teaching. This helps teachers create an authentic context for the badges available through the TLJ system. Situatedness is high when a badging learning experience is related to or within a community of practice [19]. This can be a full participation, such as engaging in conversations with the fellow STEM teachers, or the engagement can be a peripheral activity, such as observing discussions of the high-engagement webinar participants. This can also relate to the value of badge as status to the community of practitioners within which the teachers are engaged [2, 3, 13].

3.2.2 Collaboration

With the emphasis of socio-cultural considerations, cooperative, communicative, and collaborative efforts to support meaning-making are included as a dimension in the Kearney et al. [14] framework for mobile learning. Collaboration is included in this framework to permit learners multiple opportunities to articulate their understandings as they engage with others in shared meaning-making experiences. Conversation, both verbal and written, provides for valuable ongoing exchange of ideas that support the development of STEM teaching practices. In addition to shared meaning-making, collaboration is meant to include the exchange of information between learners and between learners and mentors. Through providing collaboration, cooperation, and communication opportunities, badge system designers can encourage the learners to become more connected with each other and share experiences. In the case of TLJ, this sharing goes beyond STEM content to also include information about student learning, needed resources (e.g., favorite web links), and even lesson plans that work within local contexts.

3.2.3 Personalization

Personalization is a dimension of mobile learning that allows for learner-centered education because learners can customize many factors related to their learning. Kearney et al. [8] refer to personalization as a concept that supports the "just enough, just-in-time, just-for-me" aspect of mobile learning which can allow learners to create their own pathway of learning. Agency [15, 17], a subcomponent of personalization, is high when a learner is able to negotiate and make decisions about their own education, such as what subject matter to take and what goals to set. The dimension of customization furthers personalization by allowing the learner to select what they need to meet their personal and professional goals. TLJ offers teachers the ability to both set their learning goals and to meet these goals by navigating through and choosing from available PD activities. Each activity is a smaller part of what might normally make up a larger workshop or course. This allows teachers to customize what they spend time on to meet both their personal needs and the needs of their workplace (and pupils). While the field of educational technology might also use the term personalization to refer to personalization offered through data mining patterns generated by an intelligent computer system, here, we use the term personalization to refer to providing teachers with the agency and the ability to customize.

4. METHODOLOGY

The purpose of this paper is to understand the learners' experiences with and through TLJ. We seek to use learner badging artifacts and interviews to understand how the TLJ teachers interacted with elements of a digital badging system including the goal statements, logs, materials submitted to earn a stamp or badge, and their mentor. Hickey and team [11] have categorized the funded research (both completed and in progress) into various types; our research falls into the category of 'research of badges' where researchers "study the badge system's impact and integration into learners' lives" (p. 57). Often, research of badges use includes interviews, surveys, and data mining [11], and as such, our research follows those norms.

4.1 Research Participants

Teachers were recruited from partnering organizations, with the assistance of the National Science Teachers Association and NASA, via listservs and emails. Teachers at all levels in all kinds of educational institutions were invited to participate in this professional development experience. Teachers were not compensated for participating. All teachers who expressed interest were accepted in the study, but only the 36 teachers who earned at least one stamp or badge in year one were included in this analysis. The majority of research participants were at the elementary or middle school levels—with nearly a third in each category of 0–5 years, 6–15 years, and more than 15 years of work experience. The research participants came from the United States but with the majority in the eastern and central US regions.

4.2 Data Collection

Four different types of data were collected during year one: (a) the 36 participants' stamp and badge logs and goal setting statements (n=183 user-generated documents, including stamp and badge logs and goal statements), (b) online year one evaluation survey (n=29, 80.5% of total), (c) online activity evaluation surveys for each complete badge or stamp activity (n=76), and (d) pre- and post-interviews with 11 preselected teachers. These data types are described in-depth below.

4.2.1 System Logs and User Generated Documents

The system logs captured all user-generated documents. The system logs also captured when a teacher added a badging activity to their itinerary and the recognition (stamp, badge, or both) that they received for it.

4.2.2 Summative Survey and Post-badging Surveys

A 13 question electronic survey was sent out as a summative evaluation at the end of year one to the 36 participants. The response rate was 80.5%. The survey captured opinions on the overall experience with TLJ as well as possible future improvements. The activity evaluation surveys were made available upon completion of any badging activities. The activity surveys were intended to understand the perceptions of value and quality of the individual activities and to determine if any activities needed significant revision for year two of TLJ.

4.2.3 Pre- and Post-Interviews with Focal Teachers

For the interviews, 11 teachers were strategically selected by the categories shown in Table 1. The pre- and post-interviews were conducted over the phone. Each interview lasted 45 minutes to one hour. The questions were focused on perceptions of TLJ and

other experiences with features of the badging environment and included: "Did you find value in setting a purpose statement for your learning journey?" "Did you find the itinerary an easy way to keep track of your professional development activities? and "Did you find value in the feedback you received from the education specialists that reviewed your badging logs?"

Table 1. Matrix sampling for 11 pre- and post-TLJ interviews

Work experience	Elementary Teacher	Middle School Teachers
0–5 Years	2 teachers (Lucy, Annmarie)	2 teachers (Deborah, Cindy)
6–15 Years	1 teacher (Nancy)	2 teachers (Lily, Zoe)
15+ Years	2 teachers (Erin, Hazel)	2 teachers (Barbara, Sally)

4.3 Case Study Structure

The research team designed a strategic case study [16] at three levels. At the first level of case, the badging records of all 36 teachers from year one were considered. This level of analysis was investigated through the data collected by the activity surveys, the post-TLJ survey, and the system logs. Second, a more fine-grained analysis examined 11 teachers who completed pre- and post-interviews for year one of TLJ (shown in Table 1). These interviews with teachers were used to ensure that out-of-badging data were used to enrich the analysis. To understand learner intention and learner background, these teachers serve to help contextualize the TLJ badging system in greater depth.

Third, at the most fine-grained level, we sought to elucidate learners' complex interactions with the badges, stamps, and the badging system within TLJ. To conduct this in-depth analysis, two teachers were selected — one as an example of average engagement in TLJ and the other as an example of high-level engagement in TLJ. These two teachers were strategically sampled as the typical user and the extreme user. The first participant, Barbara, received a total number of stamps and badges similar to the year one average. The second participant, Sally, completed more than double the average teacher. In this way, our examination includes both a typical learner (Barbara) and a heavily involved learner (Sally, see Figure 3). Both Barbara and Sally agreed to participate in year one as part of their summer professional learning and expressed enthusiasm when getting started. They were selected in order to focus on two people with similar backgrounds, yet they experienced different learning journeys given their interests, expertise, and personal goals as described in Section 4.4.

Figure 3. Case study participant Sally's stamps and badges.

4.4 Data Analysis

The team conducted an analysis of the TLJ experiences of the 36 teachers that participated within the year one implementation, which was run from June to August 2012. Our analysis focuses on understanding learners' experiences within the TLJ badging system and how these experiences could be useful to interactions outside the badging system—in their classrooms, in their schools, and in their lives.

The analytical process began by iteratively reading the records of 11 teachers who participated in the interviews. We made this choice because we had data from outside the TLJ system about their interests in badging, the STEM content, and their workplace conditions. The interviews focused on the teachers' experiences earning digital badges and stamps, using the online badging system to support learning, and how the overall TLJ experience connected to their educational institution.

As we read the 11 teachers' goal setting statements, badge activity logs, and interview transcripts, we applied codes for personalization, collaboration, and authenticity. First, the coded excerpts were examined within each case (e.g., one teacher's experiences). Second, the coded segments were compared and contrasted within an Excel spreadsheet to understand patterns within the badging experience of the 11 focal teachers. We used the analysis of the 11 teachers to strengthen our coding book and to develop preliminary analytical insights before moving to the third step of analysis. In the third analysis step, we examined the logs from earning badges and stamps and goal statements from all participating 36 teachers. By looking at the full dataset, we were then able to find examples and counter examples of our themes. We then turned to the activity surveys and summative surveys to compare the trends from the teachers' logs and reflections to survey responses. Throughout the analysis process, we relied most heavily on the badging activity logs and the goal setting reflections. However, the interview data and survey responses allowed us to triangulate our findings and to ensure we understood the teachers' experiences from their perspectives.

5. FINDINGS

In this section, we answer our research question about the kinds of interactions learners had with the elements of the TLJ badging system. Overall, the learners, who in this study are teachers, reported an estimated average of 13.4 hours (range 2 to 40 hours) of engagement with TLJ activities during the summer. We first describe the way that the full group of 36 teachers used TLJ's various components, with explanatory details from the 11 interview participants, especially the focal case study educators, Barbara and Sally.

5.1 Learning Organized by the Itinerary

Each participant's journey began with writing a personal learning goal statement, which allowed support for teachers in their personalized learning experience. In particular, it helped in identifying the badged activities they would want to complete over the summer and add them to a personal itinerary. As Table 2 shows, learners identified over half of the activities that they wanted to complete at the start of the experience, yet completed very few. Across the 36 teachers, 221 activities were picked during the first few weeks of the program, but only 11 were completed. Time at the beginning was spent exploring and planning for the options within the badging system, rather than earning stamps or badges. This supports the motivating learning principle to set goals described by Hickey and colleagues [11]. During year one, teachers were able to consider their goals

through drafting a focused statement and then creating a learning trajectory [11] for themselves by adding activities to their itinerary. Table 2 also demonstrates fluctuations in the engagement in PD over the time of the first year of TLJ.

Table 2. Stamps and badges completed versus the potential activities the teachers selected

		June	July	August	Total
All 36 Teachers	Selected	221	176	29	426
	Completed	11	109	34	154
Sally	Selected	4	3	0	7
	Completed	1	8	0	9
Barbara	Selected	5	2	0	7
	Completed	2	3	0	5

As evidenced by Sally and Barbara, setting more specific and attainable goals may support teacher focus while exploring, selecting, and completing PD activities. Barbara focused her goals on engaging her specific class and grade, stating that she wanted "to learn new and innovative approaches to teaching the solar system to my sixth grade students which will allow them to become more interested and excited." The PD that Barbara completed for stamp-level recognition was mostly centered on using technology in the classroom. In her initial interview, Barbara's emphasis on finding innovative teaching tools was synonymous with using technology in the classroom. In the end, Barbara completed five Solar System stamps.

Sally wanted to focus on increasing her personal knowledge to "assist my students in understanding of how the cycling of matter in and out of the atmosphere relates." Many other educators, like Sally, used their goal statements to demonstrate an interest in helping their pupils to improve. However, Sally's goal was more specific with regard to content and improving her knowledge. It is clear to see that Sally's learning goal was exactly what she pursued in TLJ content. All of the PD that she received recognition for was in the category of weather and climate, which aligned with her goals. At the end of year one, Sally completed six Weather & Climate stamps and three Weather & Climate badges.

During their post-interview, both Sally and Barbara commented that they saw value in setting purpose statements, because it helped them think critically about the PD they needed in order to meet their personal goals. By examining Barbara and Sally's goals, selections, and completed PD, we found that their focus was narrow when compared to other teachers that completed at least one stamp. From these findings, we can tell that support may be needed to help teachers in identifying focused and manageable learning goals.

5.2 Choosing a Stamp or a Badge

Personalization was also clear when analyzing the topics that learners selected. Our earlier work found that teachers most often sought the entry-level stamp as micro-credential, rather than a badge [9]: the 36 participating teachers earned 133 stamps (86.4%) and 21 badges (13.6%) across the three STEM content areas. We posit that by providing teachers the ability to make decisions about their assessment (high or low levels of mastery) provided them the flexibility to personalize their PD to align with their existing and desired expertise teachers needed for successful teaching. The total in Table 2 is compared to Barbara and Sally's experiences with TLJ and demonstrates a wide discrepancy in selected activities to do and those completed. While Barbara and Sally completed nearly as many activities as they selected for their itinerary, this is not the case with the overall 36 teachers. The full group demonstrated that the teachers selected many more than they were able to accomplish in the summer of year one. This may provide additional reasoning for creating leveled [11] badges. By offering lower-stakes or smaller granularity badges, learners may be able to select and complete more of the badges that they've identified as relevant to their learning.

Personalization was not just in the topic area but in the approach to PD. Barbara and Sally each worked exclusively on one topic. Barbara worked on solar system activities and began by exploring PD related to a general understanding of planets, next focused specifically on Mercury for three activities, and then returned to more general solar system PD again. Sally chose only weather and climate activities. Her selection was similar to Barbara's where she would vary her content focus. Sally chose PD activities with a fairly consistent alternating pattern between weather and climate content. Sally reported she was initially not enthusiastic about teaching weather and climate science in class, but she felt strongly about finding activities within the TLJ that would energize her and support her to feel more prepared to work with her middle school classes. Barbara also expressed interest in finding solar system PD activities in order to help her prepare for her lessons in the upcoming school year.

5.3 Activity Logs

To earn a badge or a stamp, teachers had to write and submit an activity log. The teachers' activity logs consisted of their explanations of how, when, and where the TLJ badging STEM materials will be used to enhance pupils' learning in their university, school, or museum. For these teachers, the TLJ content not only filled a gap in STEM resources as discussed above, but TLJ activities were used to transform current teaching practices. Teachers discussed how the TLJ material could be used to meet specific needs of their pupils. Nancy earned six Solar System stamps and one Weather & Climate stamp. In her activity logs, she wrote about the unique learning needs of individual pupils and used TLJ resources to help those diverse pupils enjoy interactive activities. For example, Nancy commented "[TLJ] helped me absorb the information….If it was useful for me, then it would be useful for learners in classroom environments." Nancy, like many other teachers in our dataset, was not only looking for quality content in the badging activities for her own learning, but in her activity log, she carefully considered how the delivery and activities of the STEM content would work in the diversity of her class.

Erin was one of the most robust TLJ users; she completed eight Engineering stamps; four Engineering badges, two Weather & Climate stamps, one Weather & Climate badge, and one Solar System stamp. In her activity logs, Erin described how she could supplement the TLJ materials to bridge the gap for pupils who had little exposure to the content or to challenge more advanced pupils. To earn her seven stamps, Nancy wrote in her activity logs how she would adapt the TLJ content for the younger elementary pupils in her classroom. Specifically, Nancy developed lesson plans that incorporated the detailed NASA images and simulations in her teaching. Nancy also reflected on how she would use the

materials from the badging system to engage her pupils more fully in the STEM content. She wrote, "students who are not highly motivated in science or mathematics and students who are not challenged enough through the use of engineering processes would enjoy the interactive activities if they are implemented and facilitated effectively."

Through the TLJ activity logs, the teachers often wrote about the topic of inclusion and of a student-centered approach. Zoe described herself as a learner who enjoys hands-on and visually rich instruction in her logs. Zoe completed two Solar System stamps. In her log, she wrote that she liked "how all the activities presented are hands-on and visual to reach a variety of learners. If the students are able to see it and manipulate it they are more likely to learn it." Barbara wrote that an activity was just "okay" for her, but then after trying to "put myself in my 6th grade students' shoes and see how they would respond," she concluded that with the help of some supplemental the activity would be "a great listening activity."

Lily used her logs to reflect on how she would use projects and classroom discussions in her upcoming school year. Lily wrote logs to earn one Solar System stamp, two Engineering stamps, three Weather & Climate stamps, and one Weather & Climate badge. She intended to use the information that she learned within the badging system to provide opportunities for her pupils to discuss in class other topics, such as climate change and land formations.

5.4 Mentor Feedback on Activity Logs

In order for a teacher to receive recognition for completing a PD activity, a reflective log was submitted for review. These required logs for completed PD also provided an opportunity to make professional learning an authentic learning experience. Sally made use of her reflections as write up for other colleagues in order to share the resources she found. Barbara reiterated the value of the reflections as a reminder for what worked and what did not for her class. Both Sally and Barbara made use of the logs to make direct applications to their own teaching.

The NASA education experts within TLJ that acted as mentors frequently provided feedback to learners related to the submitted logs for the badging activities. This feedback often included suggestions related to the topic, common STEM misconceptions they or their pupils may face, and pedagogical approaches appropriate to the STEM content presented. Barbara described her experience with the feedback as offering "really great suggestions." This dedicated support from these expert educators supports TLJ's effort to enhance the credibility of the badging activities with experts employed [11] with respect to the evaluation of logs and the awarding of badges and stamps.

5.5 Collaboration during PD Activities and after PD Activities were Completed

Discussions were supported through the use of TLJ webinars, which allowed the teachers to communicate with other teachers and with teacher educators. This communication was short-duration (1–1.5 hours) and done over an internal chat program that was available to all participants. However, it still provided benefits for teachers that did not know each other prior to the webinar. For example, in her post-interview Barbara describes her interest in having the opportunity to discuss what might work in their classrooms as evidenced by forming teacher cohorts in order to provide an on-going channel for the exchange of dialogue and artifacts such as lesson plans, student collected data, and feedback. Cohorts within TLJ could provide teachers with long-term opportunities for discussion and collaboration. Long-term benefits for teachers could include a chance for sharing successes, identifying ways to improve, and developing shared lesson plans. Short discussions provided benefits for teachers as well, such as learning how each teacher approached a lesson differently, but could also lead into a longer term engagement. For example, in one of her logs Erin writes about attending an engineering webinar, how each teacher took a turn in discussing the activity, and then how she later connected with some of these teachers through another online resource for STEM educators.

While the full TLJ analysis of the 36 teachers showed evidence that all the teachers valued the collaboration. When surveyed about future social and collaborative functionality for TLJ, 67% of the survey participants —the second most popular response— agreed with the statement: "I would like to be part of a cohort of teachers similar to me that I could work with in online workshops and other activities." More specifically, the cases of Barbara and Sally illustrate the nuance in the existing opportunities to collaborate via synchronous or asynchronous conversations with other teachers. For example, Sally stated that while she did participate in discussions, she was equally happy being an observer of the other teachers' exchanges. When asked about future collaborative opportunities, both teachers wanted more opportunities to engage in discussion like those in the webinars. Barbara further elaborated that she would like to continue the PD activity discussion later with others that completed the activity in order to share what worked and did not work when trying to implement the lesson. While the analysis of data only demonstrates relatively short duration collaboration, future iterations of TLJ would benefit from badges designed to support opportunities for peer modeling similar to that made available in the work of Ching and Hursh [6].

The collaborative aspects of TLJ reached into the teachers' work with their pupils. The teachers reported incorporating, or the intention to incorporate, materials from the TLJ badging activities in their classroom to support the development of collaborative skills in their pupils or with their peers. These collaborative aspects were reported to be included within pupils' group projects, classroom discussions, and on the teachers' websites for use with pupils and parents. Erin, as a leader in her own STEM school, needed enhanced PD that covered content beyond the standard science curriculum, given the special emphasis on STEM in her workplace. Erin wrote in her logs how the TLJ materials were already successfully incorporated into trainings that she facilitated for other teachers during the summer that emphasized collaborative skills. In addition to Erin, other teachers wrote in the activity logs that they would share the resources from the TLJ activities with their colleagues.

While designed to support both asynchronous, independent learners as well as groups of learners, these findings further support Hickey and colleagues' recommendation to promote collaboration [11]. Collaboration was an important theme among the teachers' logs. Teachers wrote about collaborating with local universities (Lily and Erin), a principal (Erin), and other teachers (Anne Marie). Teachers appreciated the feedback provided in TLJ by their mentor, and with this support, teachers felt confident enough to take on larger projects like science fairs (Lily), science academies, and leadership roles relating to their own schools PD (Erin). As teachers engaged in a community of learners, it was most often through professional learning opportunities arranged

with peers in their district or school building, as exemplified by Erin's experience.

5.6 Relevance of Badging Activities to Life Outside the Badging System

The PD that TLJ provided allowed for personalization that resulted in reports of relevance and authentic practice. Teachers were given the opportunity to submit feedback for each completed activity and among the 76 responses, 96% either agreed or strongly agreed to the statement "this activity is relevant to my teaching." Across all the teachers' responses to the post-survey, 93% agreed that the TLJ experience influenced their teaching for the upcoming school year. In addition to the PD content, the activities were also structured to require a reflection where teachers in some way consider how they might apply what they have learned back to their classroom.

Within the case study analysis, Sally explained she was able to find relevance with TLJ by being able to "hunt and choose" among all the PD activities to find what best meets her needs as a middle school teacher. While Barbara shared the resources she found with her partner teacher to make use of them in their lesson plans. Since starting to share these resources, Barbara moved closer to making her TLJ experiences situated within her district's teaching community. In addition to engaging smaller professional communities, such as the school and district level, the teachers in our study contributed to an educator online learning community that was supported by TLJ and can help to promote exchange between teachers from all across the country. Through itineraries and logs, teachers are able to map their own learning trajectories [11] of past and future learning which may help learners to visualize their badge experiences and learning over time.

For the teachers in our study, the earning of the actual stamps and badges was secondary to the learning of the STEM content area. For example, Barbara and Sally described the stamps and badges as "nice" but "not necessary" respectively. These two teachers were interested in the content for their own personal goals, as well as professional goals. Barbara wrote: "the big value is in the activities themselves." This finding demonstrates that the value of these awards of completion is currently not evident to the general educational community. Both collegial and competitive benefits can be gained from improving a teacher's ability to showcase their accomplishments and in the future, researchers and educators working on badging need to make the value of badging clearer to school districts, employers, policy makers and other opinion leaders. However, the overall opinion of badges and stamps was favorable as evidenced in the post-survey (Figure 4). When asked to select as many of the following forms or recognition you would like to receive for recognition of your work in TLJ, teachers ranked badges and stamps as highly as continuing education credits (CEUs) and below printable portfolios and letters of recognition. In this regard, future redesigns of TLJ may include a portfolio with stamps, badges, and details describing the learning goals of the PD. Portfolios like this can then be shared with colleagues, administrators, parents of the children in their classroom, or even friends and family who are interested in STEM topics.

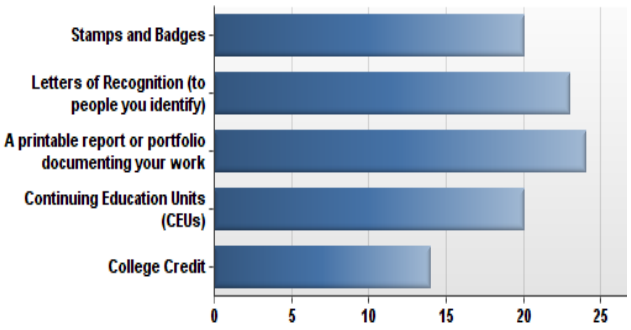

Figure 4. The types of recognition preferred by the 36 TLJ research participants.

6. DISCUSSION

This analysis focused on the experiences of 36 teachers in TLJ in regard to how TLJ badges and badging system served as a cultural tool to support STEM learning in relation to dimensions of personalization, collaboration, and authenticity (i.e., relevance). Our project was oriented to understanding learners' badge-earning trajectories as a lens into (a) the refinement of mobile learning theory that aims to support learners' reflective activities and self-expressed goals and (b) the development of technology-enhanced learning practice through the distillation of design principles applicable to badge issuers in improving their educational programming and instructional design decisions. To reflect our goal, this final section is divided into three parts. The first subsection reflects on how the activities supported or did not support learners' reflection and personal or professional goals obtainment. The second subsection considers methodological implications for studying learning with and of badges. The final section, returns to our orienting design principles [2, 3, 11, 13] to advance the field of technology-enhanced learning understandings of badges as cultural tools to mediate STEM learning.

6.1 TLJ Activities in Support of Learners' Personal and Professional Goals

From our analysis of interviews, summative interviews, and badging activity logs, TLJ teachers found themselves in decision-maker roles to personalize their STEM learning. TLJ teachers first selected their learning goals and then they identified personally applicable badging activities that they believed best met their own goals. By providing options to the teachers, the TLJ educators explored STEM content at depths and breadths that matched their individualized expertise, teaching experience, and classroom needs. For our interviews and activity logs, we know that this is important to not only their professional learning but to their personal satisfaction with the TLJ badging program. All the teachers wrote that they found benefits in making choices to personalize their STEM learning. Many wrote or spoke in their interviews that they found the direct application of TLJ materials to their classrooms and customization of the activities through TLJ logs meaningful parts of the badging experience. The importance of making connections from the badging materials to their own learning and that of their pupils was especially compelling in the excerpts from Sally's and Barbara's interviews and logs. Collaboration was a key aspect of the TLJ badging system because the teachers shared experiences and education resources with other TLJ teachers, teachers in their educational institutions, and even the pupils and parents that they served. The logs and interview data showed that TLJ provided opportunities for teacher dialogue that was relevant to their work environments.

Importantly, our data showed that the badging activities allowed the TLJ teachers to share lesson plans in relation to how the engineering, solar system, and weather and climate content could be made relevant to the lives of youth.

6.2 Methodological Implication for Studying Badging Systems with Metadata

As part of our research with badges [10], we developed techniques for studying the impact of the badging through the data and metadata contained in the badging system itself. Given that digital badging is an emerging technology without many empirical guides to studying badging impacts, an important outcome of our work for the field of technology-enhanced learning is to consider which forms of data were useful to our analysis. Most importantly, we found that no one data source served our research needs. The ability to triangulate the badging experience of learners in TLJ with the multiple data sources (i.e., pre- and post-interviews, activity surveys, summative survey, goal-setting statements, and badging logs) helped to support how teachers used badges for STEM learning and PD. We also found that collecting data at the start, during, and at the end of year one helped elucidate the learning journeys as teachers' experiences with badging grew over time. Collecting activity logs and activity surveys immediately after each activity was completed was especially important to attending to any redesign work that was needed for year two and beyond.

We also found the following data was missing that would have helped our work. During year one of TLJ, we did not collect the feedback from the mentors. This could have helped the research team to better understand how and if teachers were taking this feedback into account in badges completed afterward. Moreover, this study would also have benefited from the collection of data related to collaborative engagement between the learners and the experts and among learners while engaging in more synchronous webinar badge activities, including capturing chat logs and other forms of communication between teachers. This would have helped the research team to explore how learners supported the learning of their peers through a more in-depth focus on collaboration and the role of conversations to support learning.

6.3 Implications for Future Design Work

While we had a relatively small dataset of 36 teachers, our work is suggestive of several design principles for digital badges that can be refined through future data collection and analysis. First, the teachers in our full sample (and 11 focal teachers) personalized their badging experience in two key ways: selecting specific badging activities and then choosing an appropriate level of assessment (stamps, badges, or both) for their own expertise, goals, and classroom needs. This aspect of the design was highly valued by our research participants across multiple data sources. In order to support additional personalization in future iterations, we will continue to use goal-setting purpose statements in the initial goal-setting section of our work as well as at least two levels of assessment. Our findings from some teachers suggest that goal setting could be improved by providing examples to help guide the initial creation of goals that are attainable, specific, and focused and possibly by encouraging teachers to rework their goal statement after a certain number of badges were earned. As shown in Table 2, the teachers selected many more activities than they could have completed in the time that they allotted for themselves over the summer. Also, the teachers selected many more activities than they could have completed in the time that they allotted for themselves over the summer. To address this finding, rather than asking learners to rework their goal-setting statements after a certain number of badges are obtained, the system could be designed to automatically send out reminders asking learners to revisit their set goals at specific periods.

Given that many teachers, including Sally and Barbara, expressed interest in collaborating with others as they earned badges, more long-term collaborative opportunities can be designed into the content in our next design iteration. For instance, creating cohorts or other groupings could provide people with the ability to discuss their badging learning experiences. This cohort model would allow learners to exchange information such as data collected by their classroom and pedagogical approaches that have worked in a particular lesson. These cohorts could be set at the start of the experience or after so many badges are earned to create groupings of people with similar STEM content experiences. These collaborations might also be supported by using the TLJ system to allow teachers to create their own groupings or to match geographically located teachers together.

Finally, the logs were identified by most teachers as helpful to connect the STEM learning within the badging system to their educational institution. This suggests there may be benefits from incorporating even more supportive structures into the badging system related to the activity logging required to earn a stamp or badge. For example, within the collaborative PD webinars, reflective questions were posed to all the teachers to support their engagement in the PD activities. Given the success and the popularity of these prompts, this structure could be repeated by TLJ in other aspects of the design. For instance, specific questions could be asked as part of the reflection logs that were required to be submitted to earn a stamp. More clearly incorporating specific prompts and supporting framework into the structure of each badge or stamp activity, we posit, could help to support teachers to reflect on certain aspects of their learning or future use of what they have learned thus making their experience more authentic. Being able to focus on a few parts of their learning may help to provide an even more favorable experience with required reflections by all teachers.

7. CONCLUSION

In this paper, we explored the utility of combining perspectives on technology-enhanced learning, cultural tools, and mobile learning frameworks to design and study digital badges with K-12 teachers. From our analysis of the experiences of the teachers that participated in the project's first year, we suggest that future badging systems collect multiple forms of feedback (or data) from participants to support meaningful understanding of the badging system. We also found that including choices in the types of content, the types of assessment, and the pathway sought was important to our participants in terms of acknowledging their expertise, interests, and classroom needs. These finding support the following design principles: (a) two levels of assessment (i.e., stamps and badges) can support personalized learning, (b) mastery of learning can be demonstrated and assessed through reflective logs completed to earn a badge or stamp, (c) collaboration during and after badging activities (with colleagues within the badging system and outside of it) can provide value to the learners, and (d) establishment of relevance of badging experiences to professional practice can support the application of content outside the badging system after the recognitions are earned.

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