Learning through Participatory Design: Designing Digital Badges for and with Teens

Adam Bell
University of Washington
Seattle, WA, USA
abell42@uw.edu

Katie Davis
University of Washington
Seattle, WA, USA
kdavis78@uw.edu

ABSTRACT

Children and teens have valuable insights to offer in the design of sociotechnical learning tools and environments. Prior work has identified a range of participatory design (PD) techniques that have been used successfully to engage youth of various ages in the design process. Less understood is how youth experience and learn from their engagement in specific PD techniques. Although recent work has begun to address this understudied area, it has focused primarily on children, not adolescents. In the current study, we document the learning opportunities experienced by a group of high school students who participated in a series of six PD sessions focusing on the design of a digital badge system that recognizes and rewards out-of-school science learning. We discuss how these learning opportunities, actualized through scaffolded reflection, contributed positively to the design of the digital badge system. This work advances knowledge of how and why engaging youth in PD can contribute to effective designs of sociotechnical learning systems.

Author Keywords

Adolescents; Digital Badges; Learning Outcomes; Participatory Design; Science Education; Teens.

ACM Classification Keywords

H.5.2. User Interfaces (D.2.2, H.1.2, I.3.6): *Prototyping, User-centered design*; K.3.1. Computer Uses in Education: *Collaborative learning*.

INTRODUCTION

There is increasing recognition that children and teens have an important role to play in the design of sociotechnical learning tools and environments [18,28,38]. Youth can provide valuable insight into system usability, aesthetic design, user engagement, and learning opportunities

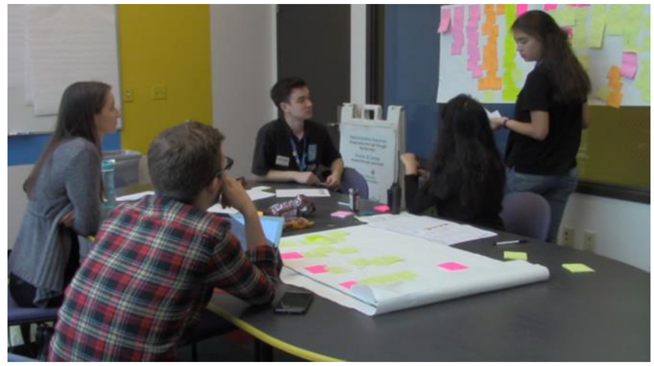

Figure 1. The design team uses the big paper prototype PD technique to identify digital badges that signify skills gained through participation in an out-of-school science program.

[11,14,21,28]. Prior work on participatory design (PD) with youth has identified specific processes and techniques for engaging youth of various ages in the co-design of learning tools and systems [11,38,39]. This work has contributed valuable insight into the relationship between the structure of PD practices and the success of the resulting designs and artifacts.

Less understood is what young people gain from their engagement in participatory design. How do they experience and make sense of their involvement in PD? How do their perspectives and understandings change? Do these changes then affect their contribution to the design process? Understanding how youth experience and learn from their engagement in specific PD techniques will give researchers valuable insight into the mechanisms by which youth contribute to effective designs and the communities in which their designs will be enacted. While recent work has begun to address this understudied area, it has focused primarily on children, not adolescents [13,30]. In light of the distinct cognitive abilities, needs, and goals associated with this stage of development [18,30], adolescents' engagement in PD processes represents a worthwhile and needed focus of inquiry.

The current study investigates the learning opportunities experienced by a group of high school students who participated in a series of six PD sessions focusing on the design of a digital badge system that recognizes and rewards out-of-school science learning. Digital badges are web-enabled icons containing rich metadata that learners can use to display and share their skills and accomplishments across

IDC '16, June 21-24 2016, Manchester, England, UK

a variety of contexts [7,32]. As sociotechnical learning systems that are gaining increased attention from education researchers, designers, and practitioners [32], digital badges represent a particularly suitable focus for this investigation. The application of digital badges to educational settings is still relatively new, and there is considerable interest in identifying effective approaches to designing badge systems that engage youth and promote their learning. As a result, there exists a rich opportunity to involve youth in the design of digital badge systems and document their experiences of the design process.

We identified six learning outcomes associated with the PD activities used to design the digital badge system: (1) teens' appreciation of their community of practice; (2) visualization of learning pathways through the science program; (3) development of metacognitive awareness of learning; (4) ownership and investment in learning; (5) academic and professional identities; and (6) a platform for science discussion and learning. We discuss how these learning outcomes, actualized through scaffolded reflection, contributed positively to the design of the digital badge system. As our focus was the design of a learning environment, it remains to be seen whether the same set of learning outcomes can be elicited when using PD to design other sociotechnical systems.

This paper contributes empirical evidence of the learning opportunities associated with specific PD techniques used with teens. By connecting these learning opportunities to the design of a digital badge system, this work advances knowledge of how and why engaging youth in PD can contribute to effective designs of sociotechnical learning systems. These insights can be used to inform best practices associated with engaging adolescents in PD in general, as well as the design of digital badge systems in particular.

BACKGROUND AND RELATED WORK

The Value of PD with Teens

Previous studies have established the value of including children and young people as design partners in the creation of new technologies [11,21,22,36,38]. Druin [11] observed that children are not simply small adults; they have distinct cognitive abilities, peer cultures, values, and goals. As such, their participation in the design process merits a distinct approach. Drawing on existing traditions of cooperative design, participatory design, and consensus participation, Druin developed *cooperative inquiry* as a method for involving children directly in the design process as design partners. By entering into partnership with researchers, children contribute to idea generation, prototype development, and user testing. They enjoy equal opportunities to share in the design of technologies in ways that are suited to their particular abilities and interests. This process results in usability designs that are tailored specifically to children. Druin observed that children themselves benefit from participating in the design process, for instance, by enjoying opportunities to build academic and social confidence.

Design studies involving teens reveal that their participation in and contribution to the design process is distinct from children's [1,6,18,21,22,28,30,38]. Yip et al. [39] compared teens' and children's participation in cooperative inquiry design sessions and found a number of differences relating to the different developmental stages of the two groups. Facilitating involvement is easier with teens because they have the cognitive and motor skills to add directly to the work. In addition, teens tend to share their opinions more, and they typically express a desire to take on leadership roles and thereby exert more control over the design process. Due to teens' busier schedules and greater independence, scheduling difficulties are often greater than with younger children. Provided these factors are taken into consideration, Yip et al. [39] found that PD techniques used with children (e.g., layered elaboration, sticky notes), can be successfully adapted for use with teens.

Previous studies have used PD successfully with teens to design learning environments [1,6,18,21,28,39]. These studies demonstrated the value of treating teens as experts of their own experiences; providing them with opportunities for teamwork and collaboration; and taking into account their values and incorporating these values into the design sessions [18]. Pazmino et al. [28] also found that incorporating opportunities for reflection proved valuable when employing PD with teens at a metropolitan zoo to improve a tablet-support tool (TST) used to engage zoo visitors. Encouraging reflection helped teens to think metacognitively about their contributions to the design of the sociotechnical artifact, in part because of the needs associated with their unique workplace environment.

The Value of PD *for* Teens

There is growing recognition that young people are not just contributing to the design process; they are themselves benefiting from their engagement [13]. In her study exploring children's participation in a technology design process, Guha [13] identified a number of social and cognitive benefits associated with children's engagement in cooperative inquiry. Social benefits included increased confidence interacting with large groups; positive relationships with adult and peer design partners; and positive affect during design activities. These social benefits were found to promote cognitive development, such as problem-solving skills associated with inquiring, brainstorming, and critiquing; literacy skills associated with reading texts to learn more about the topics being discussed in the design sessions; technological fluency associated with designing new technologies; and collaboration skills associated with working together toward a common goal.

Sociocultural learning theories offer insight into the mechanisms by which learning occurs during PD sessions. These theories frame learning as an inherently social process that takes place within *communities of practice*

[4,10,12,15,24,27,35]. Individuals build knowledge in collaboration with others and through the creation and use of artifacts. PD sessions represent a particular community of practice that affords opportunities for participants to learn about and contribute to the design process from those with greater expertise. Through a process called *legitimate peripheral participation*, novices gradually take on greater responsibility as they become more deeply embedded in the community of practice. Reflection and metacognition play an important role in the learning process [33]; by articulating their participation in and contribution to a community of practice, learners come to appreciate how their perspectives have changed—in other words, they become aware of their own learning. This view of learning underscores the fact that participation and learning are reciprocal processes that influence each other in important ways. Therefore, articulating the learning that takes place during PD sessions will contribute insight into how youth's participation contributes to the design process as they develop richer understandings about how the new sociotechnical system will be employed in their workplaces.

Designing Digital Badges

Digital badges are web-enabled icons containing rich metadata that allow learners to display and share their skills and accomplishments across a variety of contexts [7,32]. Their use in educational settings is relatively new and is based on the recognition that learning happens in many different contexts besides a traditional classroom; however, learning in these informal contexts has typically been difficult to document in any sort of systematic and visible way. Because digital badges recognize achievements at a granular level, they are uniquely able to make learning pathways visible. In so doing, learners have the opportunity to become more directly engaged in their learning, giving them a sense of agency that is often lacking in traditional classroom settings [32].

Hickey et al. [16] found that the success of introducing digital badge systems into educational settings is largely dependent on the extent to which members of the learning community value them. It follows, then, that key stakeholders in the learning environment should be directly involved in the design of badge systems in order to support a sense of investment in and ownership of badges [15]. Unfortunately, direct stakeholders are rarely part of the design team, with deleterious effects on user engagement. For instance, Davis and Singh [7] found that digital badges were not valued or used in an afterschool program that had not involved key stakeholders such as students and afterschool teachers in the design process. When asked what he thought of badges, one student responded flatly: "Horrible." Asked why he felt that way about badges, he explained: "Because I didn't make it my own. I wanted to make it look like the way I wanted to make it look" [7, p.79]. This state of affairs appears to be the norm in the design of most current badge systems in education [16]. Failing to involve learners in the design of digital badge systems makes it less likely that these systems will contribute meaningfully to the learning process.

Because digital badges represent an emerging phenomenon in educational settings, best practices in their design are still evolving [17]. Therefore, it is an opportune time to investigate what role learners can play in contributing to the design of these sociotechnical learning systems. Understanding this role requires documenting the interplay between participation and learning during PD sessions. The current study documents this interplay in the context of six PD sessions conducted with teens to design a digital badge system for use in an afterschool science program. The findings contribute new insight into best practices for involving learners in the design of sociotechnical learning systems.

METHODS

For this study, we implemented a case-study design [5,37] that included six PD sessions in which teens, program supervisors, and researchers worked together to design a digital badge system prototype to recognize the skills students gain through their participation in an afterschool science program housed at the science center of a city in the Pacific Northwest. We sought to identify the ways in which different design techniques elicited learning during the process of designing the digital badge system.

Participants

Our design team included five youth members of the afterschool science program, three program supervisors, and two researchers. The youth were between the ages of 15 and 18 and included four girls and one boy. Their involvement in the program ranged from six months to four years. The program supervisors were adults in charge of tracking the progress of approximately 70 teens participating in the program. The same design participants were involved for the duration of the study; however, each design session incorporated a different mix of participants.

Procedure

Six design sessions, each lasting two hours in length, were conducted between July and October 2015. These sessions focused on the articulation of a set of digital badges that recognize students' skills and achievements as they progress through the science program. Each session took place in a conference room at the science center so that students and supervisors could move easily between their design work with the researchers and their obligations at the science center. Snacks were provided to design participants during every session to facilitate community building [38].

During the design sessions, different PD techniques were employed to elicit iterative contributions to the digital badge system [1,21,28,36]. The researchers presented the task of each design technique through instruction, graphic organizers, or both. The PD techniques included interpretations and variations [30,36,39] on *rapport building* [11,38], *graphic organizing* [36], *mixing ideas* [14], *stickies*

[38], *comparing prototypes* [14,36], *layered elaboration* [38], *big paper prototype* [36], and *badge-user personas* [20,36]. The researchers planned each session beforehand in accordance with whatever progress had been made in the previous sessions [2,8]. Certain PD techniques were used during multiple sessions because some tasks could not be completed during a single session [39].

Design session 1 oriented the students to PD using a graphic organizer that helped them to practice design thinking and focus their ideation on the specific task ahead of them [28]. This exercise was followed by the implementation of the *stickies* design technique [38]. Using sticky notes, teens and adult supervisors listed as many potential badges as possible that could be earned in the science program, and they grouped them into categories.

Design session 2 was largely coordinated through the use of a badge idea spreadsheet, or matrix, that the researchers created as an extension of the stickies technique used in the first design session. The spreadsheet organized the stickies into categories (identified by the teens) that included *job skills, career ladder* (the name given to the structure of the program's curriculum), *life skills, new experiences, science knowledge,* and *events,* among others. Each of these categories corresponded to components of the science program and associated learning opportunities.

In design sessions 3 and 4, students continued to use the badge idea spreadsheet to enact a variation of *layered elaboration* [38]. Using different colored markers, teens highlighted the spreadsheet to signal those skills they thought would be "easy to turn into a badge" and which ones would be "difficult to make a badge." Students made these decisions, in part, by thinking about how people outside of the program (e.g., college admissions officers) would value their skills.

Later in design session 4, students began work using the *big paper prototype* PD technique [36], which was explored in greater depth during design sessions 5 and 6. In this variation on stickies [36,38,39], students worked together using sticky notes to map the digital badges on large pieces of poster paper (see Figure 1).

The *badge-user persona* [20,36] was the last PD technique employed in design session 6. The researchers prepared a graphic organizer to scaffold the teens' ideation [28]. The technique tasked the students with creating a persona of a hypothetical teen participating in the science program. The students were asked to use the big paper prototype to identify all of the badges the hypothetical student had earned, those badges she was working toward, and those she had yet to pursue.

Throughout all design sessions, focused reflections were solicited about the design process and about how the teens could best adjust their ideas and opinions in ways that would be productive in prototyping the badge system [28]. These reflections proved essential for helping students to articulate their learning and contributions to the design process.

All sessions were video-recorded and audio-recorded [9]. During the design sessions, researchers took detailed field notes that were later used for analysis [23,26]. Each session yielded design artifacts that were photographed *in situ* and then collected and stored for later analysis. Some of the artifacts were brought back to the design sessions to continue prototyping.

Data Analysis

The analysis of the design sessions was completed in three phases: (1) after each design session the first author produced a *narrative summary* using a grounded theory approach that involved identifying themes inductively from the data collected [3,26,31,34]; (2) the two authors reviewed the narrative summaries to identify *critical learning events* that occurred in association with specific PD techniques [23]; and (3) a team of four researchers viewed the critical events together for discussion and analysis [19].

Narrative Summaries

Using the artifacts, video data, photographs, and field notes, the first author wrote a chronological account of each session to describe the progress made. These narrative summaries were reviewed by the second author to maintain consistency in the reporting of facts [23,25]. The narrative summaries served multiple purposes by maintaining a timeline of progress; establishing a reference of artifact production; describing the interactions among stakeholders; and providing a framework for analysis [9].

Identifying Critical Learning Events

After six design sessions, we had a multitude of audio/visual data as well as a narrative summary for each session. Drawing on sociocultural theories of learning [4,12,24], we operationalized learning as a change in students' perspectives about their activities at the science center as they participated in a community of practice, in this case, the PD sessions. Using the narrative summaries as a reference [34], we separately reviewed each one to identify *critical learning events* using a grounded theory approach [3,9,31]. These critical events marked instances in which students displayed evidence of learning (based on our operationalization) in relation to a particular PD technique employed. A major goal of our investigation was to establish a connection between the teens' conceptions of their roles and progress in the science program and their participation in and contribution to the design of the digital badge system.

Social Viewings of Critical Events

We used the timestamps on the video data to view the critical events with a group of four researchers involved in the project. A total of three social viewings occurred over the course of one month [9]. Drawing on techniques from interaction analysis [19], we viewed each critical event multiple times, after which each researcher described his or her interpretation of the event. We discussed and debated these interpretations until we reached consensus on the primary and secondary learning outcomes associated with the critical event under discussion. For example, in our social viewing of a critical event involving the layered elaboration technique, we identified and discussed specific pieces of dialogue in which teens displayed an ownership and investment in learning (primary learning outcome). We also agreed that, while less prominent, there was evidence suggesting that the teens' academic and professional identities displayed signs of development (secondary learning outcome). We then discussed how these learning outcomes related to the teens' contributions to the overall design of the digital badge system. For this discussion, we considered the critical event in the broader context of the design artifacts produced and the progress made on the design of the badge system. This analytic approach allowed us to form systematic connections among specific PD techniques, learning outcomes, and design contributions [2,25]. Each of these connections was supported by documented evidence from the design sessions and group consensus among researchers [34].

FINDINGS

Through the use of PD, teens displayed and/or articulated the following six learning outcomes: (1) an appreciation for their community of practice; (2) visualization of learning pathways through the science program; (3) development of metacognitive awareness of learning; (4) ownership and investment in learning; (5) academic and professional identities; and (6) a platform for science discussion and learning. Table 1 articulates the primary and secondary learning outcomes associated with the PD techniques employed during each design session, as well as the resulting contributions made to the design of the digital badge system. In what follows, we summarize the PD techniques used in the six design sessions, highlighting evidence from our analysis that illustrates the learning outcomes associated with each PD technique and how these learning outcomes contributed to the design of the badge system.

Rapport Building: Establishing a Sense of Equity

Design session 1 was an introductory session that laid the groundwork for teens feeling comfortable and open as part of the design team and with the tasks they would complete together as design partners in sessions to come. We used *rapport building* [11,38] as a way to establish a sense of equity among the stakeholders through community appreciation and ownership and investment in the new technology (Figure 2). The researchers spent time getting to know the teens by talking with them casually over snacks, asking them questions about school, family, and extra-curricular activities. The friendly rapport that resulted helped all members feel like equal partners in the design process.

Figure 2. The design team eating snacks and building rapport as they begin a new design session.

Design session 2 further established rapport among the design team and comfort with the task ahead of them. During the reflective phase of design session 2, students directly questioned the legitimacy of their input in the design process. The teens realized through the ensuing conversation with the researchers that their ideas and opinions would directly affect the development of the badge system. Their roles as design partners thus became validated as influential in and important to the creation of the new technology they were designing [11,18,30,29,39]. In this way, the teens developed an appreciation for the work being done in this particular community of practice, as well as a sense of personal investment in creating badges to represent their learning at the science center (see Table 1: Sessions 1 & 2: Rapport building).

Stickies: Fostering Design Thinking

Through the stickies activity, students identified and categorized their work practices at the science center and the skills acquired through those practices. Examples of science center practices include *discovery carts*, in which students engage guests with hands-on teaching props related to specific science content (e.g., ocean acidification); *interpretation zones*, which are spaces united by a particular science theme where students initiate conversations with guests around a range of topics; and *pocket sciences*, in which students use small props to engage visitors in a science-related subject (e.g., how a butterfly sees).

When reflecting on the stickies activity (Figure 3), participants noted that organizing and categorizing their ideas was the hardest part of the design process because it revealed the richness and complexity of their learning environment at the science center. This complexity is illustrated by the large number of stickies represented in Figure 3 and the ways in which the teens depicted the connections among them. Reflecting on the stickies activity allowed the teens to articulate how their work practices at the science center contributed to their own science learning and workplace skills.

Design Session	Primary Learning Outcome	Secondary Learning Outcome	Contribution to Technological Design
Rapport building			
Sessions 1 & 2	Appreciation for their community of practice	Ownership and investment in learning	Established a sense of equity among the stakeholders in the design team which provided a more open and honest discussion, especially among teens, in regards to the technology (digital badge system) being designed.
Stickies			
Sessions 1 & 2	Metacognitive awareness of learning	Appreciation for their community of practice	Fostered design thinking among the members of the design team in order for them to think about how to best facilitate the creation of the technology (digital badge system) that would reflect the science program's community of practice.
Layered elaboration			
Sessions 3 & 4	Development of academic and professional identities	Ownership and investment in learning	The design team articulated how digital badges could represent and make visible the range of skills they acquire through their participation in the science program.
Big paper prototype			
Sessions 5 & 6	Visualization of learning pathways	Platform for science discussion	By creating a physical map of the digital badge system, the teens could place science domain knowledge into the context of their work for the end technology.
Badge-user persona			
Session 6	Metacognitive awareness of learning	Development of academic and professional identities	Promoted end-user ideation toward the conclusion of the design sessions.

Table 1. Summary of the primary and secondary learning outcomes elicited by each PD technique and the resulting contributions made to the design of the digital badge system during each design session.

Figure 3. Examples of stickies representing skills gained in the science program after students have organized and categorized them. Left: Job skills. Middle: Science knowledge. Right: Soft skills.

The students also articulated an appreciation for the community of practice in which this learning and skill development takes place. These reflections positioned the teens to think through how best to facilitate the creation of a digital badge system that would reflect the science program's community of practice (see Table 1: Sessions 1 & 2: Stickies).

A *badge design canvas* was used for more in-depth ideation about the badges identified through the stickies activity (Figure 4). Teens diagrammed badges they would like to see in their digital badge system by considering metadata such as badge criteria, evidence, users, endorsers, and values. Articulating the metadata associated with particular digital badges prompted students to think metacognitively about their learning in the science program.

With respect to the badge representing attendance and punctuality (Figure 4), for instance, students articulated the specific behaviors associated with attendance, how those behaviors would be recorded, and who would verify them. Through this process of articulation, students came to appreciate how improving in specific work practices (in this instance, attendance and punctuality) could help them to make progress in the science program overall. They also came to appreciate how digital badges could be used to represent and track that progress (see Table 1: Sessions 1 & 2: Stickies).

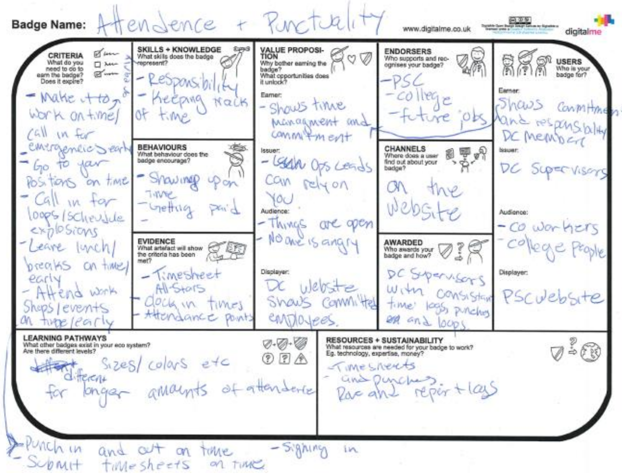

Figure 4. A badge design canvas, completed by students, that articulates a digital badge for *attendance & punctuality*.

Layered Elaboration: Articulating Digital Badges

By reflecting on the layered elaboration exercises, students came to appreciate how digital badges could signal to outsiders their accomplishments in the science program. Table 2 represents an exchange between Jane and Brenda (pseudonyms) that took place as they were reviewing the skills they had highlighted as being "easy to turn into a badge" and those they had highlighted as being "difficult to turn into a badge." In this exchange, the girls discussed how badges could be used to signal particular skills to college admissions officers and other external audiences.

Jane: I feel like it is so, so important for, like, colleges because you have to really know something to be able to deliver [information] to a lot of different ages coherently, like, so they understand it…

Brenda: And be able to, like, know how to make your—[to] make that information simpler for certain ages […] and be able to talk more about [a certain topic] if the person has more knowledge on it […] Like, I did an internship here and actually did another internship elsewhere where there was, like, TA-ing and […] the whole point of TA-ing is to be able to take knowledge and make it easier for kids to learn and understand.

Jane: Yes, and I feel like it's also very important because to give knowledge to people you have to, like, know that there's a way to be able to give it to them…

Table 2. During a layered elaboration exercise, students discuss how to use badges to represent and share their skills with external audiences.

In the excerpt above, the girls demonstrate an appreciation for presenting their skills in a form that is recognizable and compelling to external audiences. This dialogue illustrates an awareness of their developing academic and professional identities through their work at the science center, as well as a personal investment in representing those identities in an effective way (see Table 1: Sessions 3 & 4: Layered elaboration).

Table 3 highlights another instance in which the teens articulated the value of badges as they reflected on the layered elaboration exercises. In this excerpt, Brenda indicates her appreciation for the work she and her peers have done in the science program and how this work contributes to the development of their academic and workplace identities.

Brenda: I think we're, like, finally starting to, like, understand, like, what a badge is and, like, what—how to get the badges, what are the most important, like, stuff that we need badges for […]

Researcher 2: What's "stuff" to you? Skills for the job? Or, skills for life? Or, skills for just the science center?

Brenda: I'm more like—no—I'm like, you know […] Stuff I think we work on the most in our job and stuff that I feel like this job helps us improve on the most, if that makes sense—yes. Also stuff that makes us look good for, like, colleges.

Researcher 2: Sure. Are you seeing that kind of taking shape in the badge system?

Brenda: Yes, it's like I never really thought about our job that much before—on, like, what we've already done […]

Table 3. A student reflects on her learning in the science program during a layered elaboration exercise.

Big Paper Prototype: Creating a Visual Map of the Badge System

The big paper prototype activity allowed the students to see how badges could represent pathways through content domains and workplace practices at the science center. This design session also fostered conversation among the students about their science domain knowledge (see Table 1: Sessions 5 & 6: Big paper prototype).

Choosing a Learning Pathway

The big paper prototype encouraged students to think about the different learning pathways available to them in the science program. In the first phase of this activity, students listed on stickies all of the workplace activities associated with each part of the program's career ladder (Figure 5, Left).

This mapping helped them to visualize the number and sequence of activities associated with different parts of the science program's curriculum. On a second sheet, students grouped badges according to science domain "content clusters" such as climate, biology, physics, and health. Under each category, they listed specific skills they learned while engaging in various workplace activities (Figure 5, Right). The design team also discussed how the resulting learning pathways could be useful for identifying where a student needs to continue learning, or where a personal interest could be pursued.

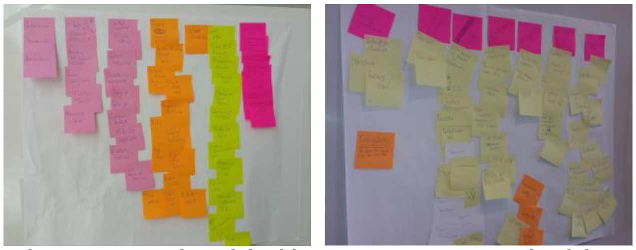
Figure 5. Examples of the big paper prototype. Each sticky represents a potential badge. Left: Science center career ladder pathways. Right: Science domain learning pathways.

Table 4 depicts a small piece of discussion that centered around visualizing these learning pathways, illustrating the students' desires to be able to choose the badges they want to earn (see Table 1: Design Session 5: Big paper prototype).

Brenda: I know. I think it's like a personal badge, like, you know where we were talking about, like, the personal stated badges …

Donna: Everybody is not, like, required to get all these badges. You're not, like, incomplete, if you don't have them. They are just options of things. You can be like, "Oh yes, I'd do that. Gimme."

Jane: And it really, like, it shows you what you haven't done and then you're, like, "Oh wow," that's something I can do.

Carrie: Yes, if you're feeling bored.

Table 4. Teens discuss how badges could offer different learning pathways during the big paper prototype exercise.

The awareness of learning pathways reflected in this excerpt helped the students focus their ideation on badges that were meaningful to them, but also on those that would be available to other science program members who may find different activities more meaningful than others.

Negotiating Science Knowledge

In the big paper prototype activity, students identified badges that represented the acquisition of science knowledge. As the teens listed out the possible badges, they parsed the different areas of science where each of the badges would exist. For example, the teens engaged in a debate about the shared concepts of *physics* and *space* in order to determine how they would delineate each type of science knowledge through the sociotechnical system they were designing. In this discussion, they compared the different ways their respective schools approached the teaching of physics, including specific concepts that were and were not part of their schools' curricula. Through this discussion, students came to appreciate that science domains could be defined and presented in a variety of ways and that scientific knowledge is not necessarily unitary or fixed (see Table 1: Sessions 5 & 6: Big paper prototype).

Badge-User Personas: Identifying the Needs and Goals of End-Users

The badge-user persona promoted students' metacognitive awareness of their learning because it allowed them to connect the digital badges they had identified to a potential user and his or her goals in the science program (Figure 6). Also, by creating a specific user-identity for the badge system, the students began to understand how the science program could be a unique experience for every individual, especially if individual students were able to "level up" in certain skills.

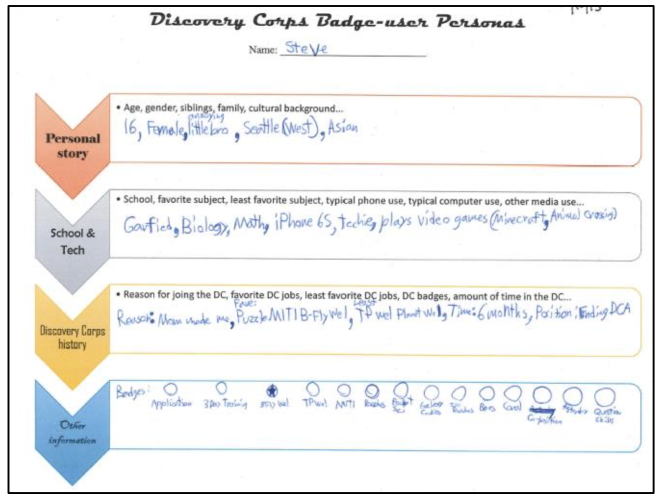

Figure 6. The students created a badge-user persona for a hypothetical student and her participation in the program.

Researcher 1: Is there—I was just thinking, so it's a really good question, though. Can you level up [develop expertise] on something that is a very kind of defined thing? But maybe—leveling up is partly getting a bit better, I know—but maybe it's also partly just doing it a lot and you will get better at it when you do it a lot.

Carrie: Well, I think a lot of the butterfly welcome [exhibit] is, like, when you start, you basically just say, more or less, whoever you shadowed, like, [what they] said and the more you do [the position], the more you become—like, you turn it into your own words, and it kind of like flows off of your tongue. You're not just like trying to avoid the words just like, "Hey, this is, like, how it works" and you get a lot more better at it—ha, 'more better'—attempting to be like, "oh," like, "I can see people aren't wearing coats at all. I don't need to tell them 'please hang up your coat.'

Table 5. A student reflects on expertise in a community of practice during the badge-user persona exercise.

Table 5 offers a glimpse into the design team's discussion as they articulated how a hypothetical student might earn badges in the program. During this discussion, the students were encouraged to reflect on all of the badges they had delineated to this point and how a hypothetical student would navigate them in a systematic way.

In this discussion, the teens displayed metacognitive awareness of their learning because they thought about how their jobs were like apprenticeships. That is, they learned from the people whom they shadowed at different exhibits on the floor of the science center. As they moved from novice program members to experts during these apprenticeships, the teens became more confident in their roles and could make on-the-spot decisions based on their deepening knowledge and experience. Reflecting on this process helped the teens further appreciate the digital badge system and how it could promote their academic and professional identities (see Table 1: Design session 6: Badge-user persona).

DISCUSSION

The findings from the current study extend prior knowledge about the nature of teens' participation in PD and the processes by which they contribute to the design of sociotechnical learning systems. Our focus on digital badges was deliberate and opportune in light of the evolving nature of best practices in their design for educational settings [17]. Like previous work [13], we found that youth benefit from rich learning opportunities as they engage in PD. Using a sociocultural learning theory perspective [4,10,12,15,24,27,35], we identified six learning outcomes associated with specific PD techniques: (1) teens' appreciation for their community of practice; (2) visualization of learning pathways through the science program; (3) development of metacognitive awareness of learning; (4) ownership and investment in learning; (5) academic and professional identities; and (6) a platform for science discussion and learning (Table 1). These learning outcomes—identified by inviting participants to reflect on their participation in the design process—helped teens contribute distinct and valuable insights to the design of the digital badge system. Moreover, teens were unique design partners in the PD process because they had a strong ability to share thoughts honestly and productively as they developed an understanding of how this new technology would be used in their science learning community [18,29,30].

As seen in Table 1, the PD activities that promoted *rapport building* [11,38] among design members supported an appreciation of participants' community of practice (primary learning outcome) and a sense of ownership and investment in their learning at the science center (secondary learning outcome). These learning experiences established a sense of equity among the design team members, which provided more open and honest discussion, especially among teens, in regards to the technology being designed (contribution to technological design).

The *stickies* PD technique [38] pushed teens to develop a metacognitive awareness of their learning at the science center (primary learning outcome) and further encouraged them to appreciate the community of practice in which they were situated (secondary learning outcome). Through reflection on the use of stickies, all of the stakeholders improved in their design thinking practices in order to better facilitate the creation of a technology that reflects the science learning community (contribution to technological design).

A variation on *layered elaboration* [38] contributed to the development of teens' academic and professional identities (primary learning outcome) and supported their ownership and investment in the types of learning they experienced in their out-of-school science program (secondary learning outcome). As a result of these learning opportunities, the teens were able to articulate how digital badges could represent and make visible the range of skills they acquire through their participation in the science program (contribution to technological design).

The implementation of the *big paper prototype* technique [36] was used extensively to help students visualize their learning pathways through the science program (primary learning outcome). This practice also offered a platform for science discussions (secondary learning outcome). By creating a physical map of the digital badge system, the teens could place science domain knowledge into the context of their work for the end technology (contribution to technological design).

Finally, the *badge-user persona* [20,36] advanced the teens' metacognitive awareness of their learning (primary learning outcome), and it pushed them to think about their own academic and professional identities (secondary learning outcome). These learning opportunities supported the design of the technology because ideation focused on the needs and goals of end-users of the digital badge system (contribution to technological design).

The learning opportunities documented in this study are fundamentally social in nature, illustrating the value inherent in the collaborative aspects of PD [13]. By working together to list the skills they acquire through their participation in the science program, identify badges to correspond with those skills, and think through how different stakeholders might interpret and use badges, the teen participants developed a new perspective on their experiences at the science center. For instance, they came to appreciate how specific activities and skills were linked and built on each other (visualizing learning pathways), and they articulated how certain badges might become part of their academic and professional identities. Importantly, these changes in perspective were manifest during moments of explicit reflection, suggesting that reflection is an essential part of learning through PD [28,29,33].

By connecting the six learning outcomes to specific design contributions, we show how learning through PD did not just benefit design participants but also advanced the badge system design in meaningful ways. Reflecting on and articulating their own learning in the science program optimally positioned the teen design partners to then represent that learning through digital badges. An outside badge developer who simply read about the program or interviewed program members would be hard-pressed to capture and represent the full range and depth of learning due to their lack of firsthand experience with the program.

For instance, an outside badge developer could learn about the program sufficiently well to appreciate that public speaking plays an important role in many of the jobs that students take on at the science center (Figure 3, Right). However, they would be less likely to know which jobs require the greatest skill in public speaking, the specific sub-skills associated with distinct jobs, or how much practice is required to develop those skills. As a result, they would be less well positioned than teen design participants to develop a comprehensive and representative sequence of badges that articulates a public speaking learning pathway. Similarly, there are several jobs at the science center that develop students' knowledge of climate change. While an outside developer could learn the names of these jobs, it would be harder for them to understand how they relate to and build on each other. The PD techniques used in the current study enabled teens to develop such an understanding by reflecting on their learning experiences in the science program. These examples illustrate the value of involving stakeholders directly in the design of digital badge systems [17].

LIMITATIONS AND FUTURE WORK

The findings reported in this paper address the first six design sessions in an ongoing badge system design process. This group of sessions formed a coherent unit for the purposes of our investigation insofar as the design team was able to articulate all of the skills associated with the science program and then represent those skills through named badges. However, these sessions did not involve the development team that will actually build the badge system, and so we do not yet know how the current ideation will ultimately be represented in a fully functional badge system. Future work will explore the interplay between the initial ideation documented in this paper and the process of developing the badge system.

Future work will also investigate the implementation of the badge system, documenting the extent to which the contributions made by the teen design partners translate into successful user engagement. The knowledge gained from such an investigation can be compared against existing badge systems that have not been designed with stakeholder input in order to gauge the precise value of this design approach. It would also be useful to compare the learning outcomes and design contributions associated with using PD to develop other learning tools and systems besides digital badges in order to ascertain whether these findings are unique to the design of digital badges or whether they can be generalized to other design tasks. Moreover, it would be worthwhile to investigate learning outcomes in the design of sociotechnical systems that do not have a specific learning focus.

CONCLUSION

The current study investigated a series of six PD sessions that engaged teens in the design of a digital badge system that recognizes the skills that high school students gain through their participation in an out-of-school science program. The results of the analysis demonstrate six learning outcomes associated with specific PD techniques, which deepened students' appreciation for and participation in the science program. Through these learning experiences, the teen design partners were able to contribute effectively to the design of the digital badge system. Thus, the findings demonstrate how the learning opportunities presented through PD position youth as valuable contributors to the design process. These insights can inform best practices for engaging youth in the design of digital badge systems, an emerging phenomenon in education settings that is still in the process of establishing guiding design principles. They may also have broader applicability with respect to engaging youth in the design of other types of sociotechnical learning systems.

SELECTION AND PARTICIPATION OF CHILDREN

This work took place at a science center in an urban city in the northwest. Five teens, ages 15-18, at the science center volunteered to participate in this study. They were paid during their participation as part of their hourly wage associated with employment at the science center. This project was approved by the institutional review board associated with the authors' university. All participants were presented with consent forms that explained the purpose of the research, the nature of their participation, and how collected data would be used. Parents of youth signed consent forms allowing us to video record design sessions, take notes, and collect design artifacts for subsequent analysis.

ACKNOWLEDGMENTS

We would like to thank Caroline Pitt and Ada Kim for their help with social viewings during the data analysis for this paper. Also, we appreciate the feedback provided by Caroline Pitt on an earlier version of this paper. We are grateful for the resources provided by the National Science Foundation (Award 1452672) that made this work possible.

REFERENCES

1. Anne Adams, Yvonne Rogers, Tim Coughlan, Janet Van-der-Linden, Gill Clough, Estefania Martin, Pablo Haya, Trevor Collins. Teenager needs in technology enhanced learning. *Workshop on Methods of Working with Teenagers in Interaction Design,* CHI, (2013).
2. Philip Bell. (2004). On the theoretical breadth of design-based research in education. *Educational psychologist* 39, 4: 243-253.

3. Richard E. Boyatzis. (1998). Transforming qualitative information: Thematic analysis and code development. Thousand Oaks, CA: Sage.
4. Robert E. Cole. (1989). Strategies for Learning: Small-group activities in American, Japanese, and Swedish Industry. Berkeley: University of California Press.
5. John W. Creswell, Dana L. Miller. (2000). Determining validity in qualitative inquiry. Theory into practice, 39, 3: 124-131.
6. Karin Danielsson, Charlotte Wiberg. (2006). Participatory design of learning media: Designing educational computer games with and for teenagers. *Interactive Technology and Smart Education* 3, 4: 275-291.
7. Katie Davis, Simrat Singh. (2015). Digital badges in afterschool learning: Documenting the perspectives and experiences of students and educators. *Computers & Education* 88: 72-83.
8. Design-based Research Collective (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher* 32, 1: 5-8.
9. Sharon J. Derry, Roy D. Pea, Brigid Barron, Randi A. Engle, Frederick Erickson, Ricki Goldman, Rogers Hall, Timothy Koschmann, Jay L. Lemke, Miriam Gamoran Sherin, Bruce L. Sherin. 2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences* 19, 1: 3-53.
10. Ole Dreier. (2009). Persons in structures of social practice. *Theory & Psychology* 19, 2: 193-212.
11. Allison Druin, A. (2002). The Role of Children in the Design of New Technology. *Behaviour and Information Technology* 21, 1: 1-25.
12. Yrjo Engestrom, Annalisa Sannino (2010). Studies of expansive learning: Foundations, findings, and future challenges. *Educational Research Review* 5, 1: 1-24.
13. Mona Leigh Guha. (2010). Understanding the social and cognitive experience of children involved in technology design processes. Ph.D. dissertation. University of Maryland, College Park.
14. Mona Leigh Guha, Allison Druin, Gene Chipman, Jerry Alan Fails, Sante Simms, Allison Farber. (2004, June). Mixing ideas: a new technique for working with young children as design partners. In *Proceedings of the 2004 conference on Interaction design and children: building a community* (pp. 35-42). ACM.
15. Kris D. Gutierrez, Barbara Rogoff. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher* 32, 5: 19-25.
16. Dan T. Hickey, James E. Willis, Joshua D. Quick. (2015). Where badges work better. Educause Learning Initiative. *Retrieved from https://net.educause.edu/ir/library/pdf/elib1503.pdf*.
17. Dan T. Hickey, Nate Otto, Rebecca Itow, Katrina Schenke, Cathy Tran, Christine Chow. (2014). Badges Design Principles Documentation Project. January Interim Report.
18. Ole Sejer Iversen, Christian Dindler, Elin Irene Krog Hansen. (2013) Understanding teenagers' motivation in participatory design. *International Journal of Child-Computer Interaction* 1, 3-4: 82-87.
19. Brigitte Jordan, Austin Henderson. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences* 4, 1: 39-103.
20. Plinio Thomaz Aquino Junior, Lucia Vilela Leiti Filgeurias. (2005). User Modeling with Personas. *In Proceedings of the El Congreso Latinoamericano de la Interacción Humano-Computador* (CLIHC'05) (pp. 277-282). ACM.
21. Eva-Sophie Katterfeldt, Anja Zeising, Heidi Schelhowe. (2012, June). Designing digital media for teen-aged apprentices: a participatory approach. *In Proceedings of the 11th International Conference on Interaction Design and Children* (pp. 196-199). ACM.
22. Finn Kensing, Jeanette Blomberg. (1998). Participatory Design: Issues and Concerns. *Computer Supported Cooperative Work* 7: 167-185, Kluwer Academic Publishers, 1998.
23. J. Richard Landis, Gary G. Koch. (1977). The measurement of observer agreement for categorical data. *Biometrics* 33, 1: 159-174.
24. Jean Lave, Etienne Wenger. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge [England]. New York: Cambridge University Press.
25. Joseph A. Maxwell. (2005). *Qualitative research design: An interactive approach* (2nd ed.). Thousand Oaks, CA: Sage Publications.
26. Sharan B. Merriam. (2009). *Qualitative research: Guide to design and implementation*. San Francisco, CA: Jossey-Bass.
27. Na'ilah Suad Nasir, Victoria Hand. (2008). From the Court to the Classroom: Opportunities for Engagement, Learning, and Identity in Basketball and Classroom Mathematics. *Journal of the Learning Sciences* 17, 2: 143-179.
28. Priscilla F. Jimenez Pazmino, Brian Slattery, Leilah Lyons, Benjamin Hunt. (2015). Designing for youth interpreter professional development: A sociotechnologically-framed participatory design approach. *IDC 2015*. Medford, MA. 1-10.
29. Erika S. Poole, Tamara Peyton. (2013, June). Interaction design research with adolescents: methodological challenges and best practices.

In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 211-217). ACM.

30. Janet C. Read, Matthew Horton, Ole Iversen, Dan Fitton, Linda Little. (2013) Methods of working with teenagers in interaction design. *In CHI '13 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '13). ACM, New York, NY, USA, 3243-3246.
31. Catherine Kohler Reissman. (2008). *Narrative methods for the human sciences.* Thousand Oaks, CA: Sage.
32. Michelle M. Riconscente. Amy Kamarainen, Margaret Honey. (2013). STEM badges: Current terrain and the road ahead. *Retrieved from New York Hall of Science website: http://badgesnysci.files.wordpress.com/2013/08/nsf_stembadges_final_report.pdf.*
33. R. Keith Sawyer. (2006). Introduction: the new science of learning. In R. K. Sawyer (Ed.) *The Cambridge handbook of learning sciences* (1-18). New York: Cambridge University Press.
34. Peter Smagorinsky. (2008). The method section as conceptual epicenter in constructing social science research reports. *Written Communication* 25, 3: 389-411.
35. Lev S. Vygotsky. (1987). *The collected works of L.S. Vygotsky: Problems of general psychology including the volume thinking and speech* (N. Minick, Trans. Vol. 1). New York, NY: Plenum.
36. Greg Walsh, Elizabeth Foss, Jason Yip, Allison Druin. (2013). FACIT PD: A framework for analysis and creation of intergenerational techniques for participatory design. *Proceedings of the 31st International Conference on Human Factors in Computing Systems*. (ICHFCS'13) (pp. 2893-2902). ACM.
37. Robert K. Yin. (2008). *Case study research: Design and methods* (Vol. 5). Thousand Oaks, CA: Sage Publications, Incorporated.
38. Jason Yip, Tamara Clegg, Elizabeth Bonsignore, Helen Gelderblom, Emily Rhodes, Allison Druin, A. (2013). Brownies or Bags-of-Stuff? Domain expertise in Cooperative Inquiry with children. *In Proceedings of the 12th International Conference on Interaction Design and Children* (IDC '13) (pp. 201-210). ACM.
39. Jason Yip, Elizabeth Foss, Mona Leigh Guha. (2012, October). Co-designing with adolescents. In *Proceedings of the Designing Interactive Technology for Teens Workshop at NordiCHI*. Copenhagen, Denmark.