A case study of a five-step design thinking process in educational museum game design

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Abstract

We present a case study in the design of an educational video game about collecting, curating, and museum operations. A five-step cyclic design thinking framework was used by the studio during the design and development of the game, and the team was simultaneously the subject of a rigorous and detailed ethnographic study. Three stages of the game's design evolution are presented through the lens of the design thinking framework. The team's practice-based research is triangulated with our empirical data to produce four key findings: (a) that empathy for learning context is critical in aligning designs with learning objectives; (b) that meeting with stakeholders spurs empathy-building; (c) that there is a tension between horizontal and vertical slicing that is revealed by design thinking processes; and (d) that iterative design processes challenge conventions of higher education.

Keywords: Game design, serious games, design thinking, empathy, museum games, Scrum, practice-based research, qualitative research, ethnography, immersive learning, creative inquiry

Introduction

We present a case study in the design of *Museum Assistant: Design an Exhibit*, an educational video game. The game was created by Root Beer Float Studio in Muncie, Indiana, between January 9 and April 27, 2012, in cooperation with The Children's Museum of Indianapolis. The game places the player in the role of a museum volunteer who is tasked with creating digital exhibits from the museum's collection. The design evolution reveals three distinct, named stages: Photo Museum, Mystery at the Museum, and Museum Assistant. Our analysis is based on the factors, processes, and people that influenced these stages, leading to four key findings relevant to serious game design and development.

The studio employed a five-step iterative design thinking framework. *Design thinking* provides a human-centered view of technological artifact design and is therefore an appropriate tool for serious game design. The specific design thinking framework used at Root Beer Float Studio gives careful attention to the qualities of end-users and the utility of the system. The studio's application of the framework constitutes a practice-based evaluation, one that is held to high levels of rigor in accordance with the characteristics of practice-based research (Biggs & Büchler, 2007). The findings we describe in this paper are grounded in empirical data gathered through a concurrent ethnographic study of the lived experience of studio members and their environment.

It is significant that Root Beer Float Studio was comprised entirely of undergraduate students who collaborated in a full-time work environment; further details of this educational environment are provided in the study context section below. This environment exemplifies *immersive learning*, a high-impact pedagogical and curricular practice that provides important contextualization for this work (Gestwicki & Morris, 2012).

A review of influential perspectives on design thinking provides justification for the studio's approach, which is necessary in order to form a bridge to the game design literature. We then provide more details on the studio, including salient characteristics about studio members, the work environment, and the project goals. We also provide details about our empirical methodology and methods, which serves to contextualize our findings and conclusions.

Design Thinking

Definition and history

The phrase "design thinking" was popularized by Rowe (1991) to refer to the ways in which designers approach design problems, although design researchers have been studying the process for decades (Schon, 1983; Simon, 1969, for example). In contemporary use, the term refers to both conventional design domains as well as in different contexts such as business (Brown, 2009; R. L. Martin, 2009) and computing (Brooks, 2010). Despite such disparate uses and application, design thinking can be seen as a grounding framework for multidisciplinary teams to communicate and to coordinate activity (Lindberg et al., 2010).

Dorst (2011) articulates how a core element of expert design is *framing*—dealing with the paradoxes that arise from conflicting considerations in order to create value. Framing can be understood as a form of abductive reasoning; that is, it deals with developing hypotheses that could account for situations or observations. In the case of design problems that do not have closed-form solutions, the designer is dealing with unknowns of what will be designed as well as how it will create the desired value.

We note that these paradoxes arise in game design but are magnified in serious game design; this is because the educational domain provides another axis for conflict.

There is not one definitive model for design thinking. Hekkert & van Dijk (2011) presents a process for industrial design based on alternating deconstruction and reconstruction. Aspelund (2006) presents a seven step sequential model to design that isolates design from production issues. Brown (2008, p.88–89) presents a nonlinear process with three interconnected phases—inspiration, ideation, and implementation—which can be further characterized by smaller-scale steps and reflective questions. In an articulation specifically for designers of school-based learning experiences, Fierst et al. (2011) describe a five-step model in which iteration is relegated to the final phase, *evolution*. A phenomenological perspective is applied by Poulsen & Thøgersen (2011) in their study of the design of a video card game, resulting in a three-phase design thinking process consisting of *focus*, *reflect*, and *reframe*; this model reinforces the idea that framing is essential to design thinking (Dorst, 2011).

The design thinking model presented by Kembel (2009) is notably different for its explicit treatment of empathy. His is a five-step cyclic model consisting of *empathy*, *problem definition*, *ideation*, *prototyping*, and *testing*. Empathy arises from a deep understanding of the stakeholders and their needs. It goes beyond merely involving users in a design process and considering their articulated wants and needs: in this model, empathy requires an anthropological approach to understanding users and their environments (Kelley, 2005; Schell, 2008). When considering the context of serious game development, this calls to mind the ecological approach, which recognizes the contextual and embodied natures of knowledge (Gibson & Pick, 2003; Linderoth, 2010).

Design Thinking and Game Design

All games teach something through their play (Koster, 2004; McGonigal, 2011), but there is a particular challenge in designing a "serious game" to both entertain and educate. Linderoth (2010) identifies the most difficult aspect to be *transfer*, that what is learned in one context can be applied in another; transfer is especially challenging given the embodied and context-sensitive nature of learning (Gibson & Pick, 2003). Schaller (2011) describes the challenge of museum game design as a balance of entertainment and accuracy, building on the tradition of Roberts (1997).

The game design literature provides various formal design models, although none in our survey included explicit treatment of design thinking. Schreiber (2009, Level 2) presents an iterative four-step model for designing analog games and a double-looped model for digital games. "Design" itself is included as a step in these processes, demonstrating how the term can have confusing, multiple meanings; this sentiment is captured in the famous design aphorism, "Design is to design a design to produce a design" (Heskett, 2005, p.3). Fullerton (2008, p.15) presents a four-step iterative process consisting of generating ideas, formalizing ideas, testing ideas, and evaluating the results; this is similar to the iterative design process consisting of "prototyping,

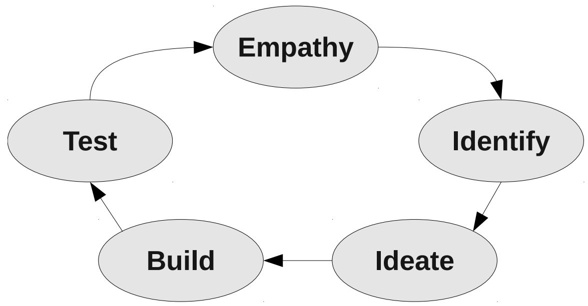

Figure 1. Five-step design thinking process

play testing, evaluation, and refinement" presented by Salen & Zimmerman (2004, p11). McGuire & Jenkins (2009) do not provide an explicit iterative process, but they do encourage building prototypes, the first by at least a quarter through the project schedule. A useful summary of prototyping processes was recently presented by Eladhari & Ollila (2012).

The design thinking process studied and employed by our participants was based on Kembel (2009), and an overview of the process is shown in Figure 1. One begins with *empathy* for the stakeholders, a group that includes both the players as well as internal and external agencies; in our study, the university and the studio's community partner were included in consideration as stakeholders (the specific details of which are described in more detail below). This leads to *identification* of actual design problems. *Ideation* is the seeking of potential solutions to the identified problems. These solutions are *built* and then *tested*. The link from *test* back to *empathy* is critical for our study, as will be explained below.

Study Context

In this section, we describe the confluence of people, places, and institutions that we studied. This serves to contextualize both our methods and the ethnographic study of design history that follows.

Immersive Learning

Our study took place in a Spring 2012 seminar at the Virginia B. Ball Center for Creative Inquiry at Ball State University, a large research university in Muncie, Indiana. The Virginia Ball Center (VBC) sponsors four semester-long seminars each year during which teams of students work with a faculty mentor on an interdisciplinary problem. Students at the VBC earn fifteen credit-hours for their participation, and this full-time obligation comprises their entire coursework for one semester. Similarly, the faculty mentor is given a sabbatical-like release from regular duties in order to be fully devoted to the seminar.

The VBC is housed at the Kitselman Center, a renovated mansion in a residential neighborhood a mile removed from the main university campus. A VBC seminar

Figure 2. Root Beer Float Studio logo

is designed to be an *immersive learning* experience (Gestwicki & Morris, 2012; McKillip, 2009; Blackmer, 2008). That is, a VBC seminar: (a) carries academic credit; (b) is student-driven and faculty mentored; (c) generates a product; (d) involves a team working on an interdisciplinary problem; (e) involves community partners; (f) focuses on student learning outcomes; and (g) helps students define a career path or otherwise make connections to industry. We note that immersive learning shares characteristics with the high-impact learning practices identified by Kuh et al. (2010), particularly with respect to the engagement of students within a team and with the community.

In Spring 2012, Computer Science Prof. Gestwicki led a fifteen-week seminar entitled, "Games, Fun, and Learning," during which he and the students employed practice-based research to design and develop an educational computer game. The team christened themselves *Root Beer Float Studio* and worked together from 8AM to 4PM, Monday through Friday. The community partner was the Children's Museum of Indianapolis—the largest children's museum in the world—and the expected outcome of the seminar was a Web-based educational video game.

The team consisted of thirteen undergraduates: eight Computer Science majors, one with a second major in Economics; one Music Technology major; one History major; one Visual Communications (Graphic Design) major; one student with majors in Electronic Art and Animation and Psychology; and one student with majors in Theater and Creative Writing. This distribution of skills matches the heuristics suggested by Cockburn (2007, p.59) for software development teams. More than half the team had no prior experience with game design and development. One of the Computer Science majors had taken an honors colloquium on history education game design, and she and five other Computer Science majors had previously worked on two major educational game development projects: an American Civil War history game (Gestwicki & Morris, 2012) and an unreleased historical archaeology simulation game.

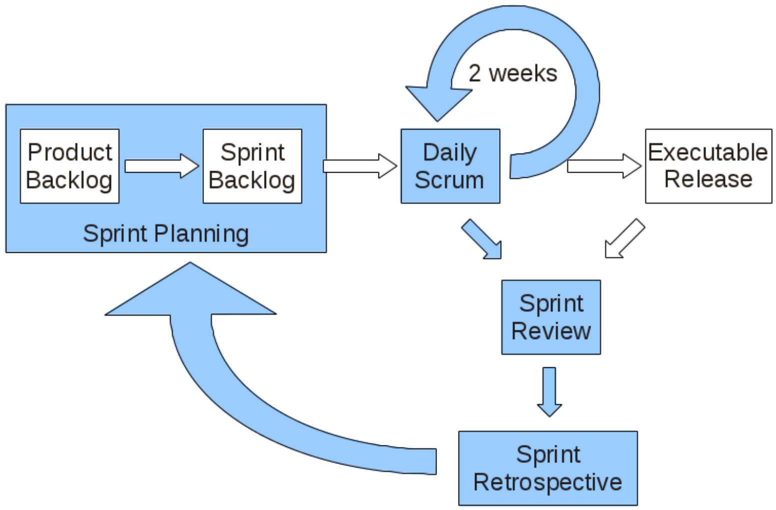

Figure 3. Overview of Scrum. Shaded regions represent human activities and unshaded regions represent the flow of Scrum artifacts. (Figure originally published in Gestwicki & Morris (2012).)

While most of the semester was spent on design and development activities, there were also guest speakers, reflective writing exercises, discussions, and reading groups. The team read *A Theory of Fun for Game Design* (Koster, 2004), during the weeks leading up to the seminar, and several meetings during the semester involved discussions based upon this germinal work. Two reading groups within the team were known informally as the "Computer Science Group" and the "Arts and Humanities Group." The former group read, discussed, and applied *The Clean Coder* (R. C. Martin, 2008), while participants in the latter group read and discussed a variety of relevant books during the semester (Dille & Platten, 2008; Gee, 2004; McGonigal, 2011, for example).

Structure of the fifteen-week seminar

The first week of the semester was used as an introduction to game design. The focus of this week was non-electronic games, inspired in part by Costikyan (1998), and some of the activities during the week were adapted from Schreiber (2009) and Fullerton (2008). The team also made their first formal visit to the Children's Museum of Indianapolis to discuss design objectives.

The remaining fourteen weeks were organized following industrial best practices of agile game software development. The team used Scrum (Schwaber & Sutherland, 2011) as a team management framework, of which Figure 3 provides an overview. Scrum facilitates an iterative and incremental development methodology and can be characterized as an agile approach (Beck et al., 2001). Each iteration is called a *sprint*, and the output of each sprint is a *potentially shippable product*. This product may be an executable release as shown in Figure 3, but it may also take the form of design documentation, Web sites, physical prototypes, marketing plans, and so on. Root Beer Float Studio used two-week sprints, which is the shortest duration recommended for game development with Scrum (Keith, 2010, p65). This allowed for the maximum number of iterations during the semester, which was critical since the duration of the semester—and therefore the deadline of the project—was an inviolable constraint.

Scrum provides a framework to be adapted to local needs (Schwaber & Sutherland, 2011), and so discussion of the team's particular practices merits brief discussion. Many of our specific practices come from recommendations provided by Keith (2010). Before each sprint, in the role of *Product Owner*, Gestwicki created and maintained a prioritized list of user stories (Cohn, 2004, 2006). These user stories were derived from the design work conducted by the team, including prototypes, documentation, team meetings, meetings with the community partner and other content experts. The team began each sprint in the *Sprint Planning* meeting, during which they estimated the size of the user stories and committed to completing a subset of them within the sprint. The team also articulated the tasks necessary for satisfaction of the user stories and estimated the hours of effort required for each. Gestwicki also served as *Scrum Master* for the project, acting as facilitator for meetings such as the Sprint Planning meeting.

Each morning during the sprint, the team met for the eponymous *Daily Scrum*—a short stand-up meeting during which each person reports on what they had done since the previous day, what they have planned for the day, and what impediments stand in the way. Following Keith (2010), the progress on stories and tasks was recorded on a task board (Figure 4 and summarized in the sprint burndown chart (Figure 5). We note that one of the roles of the Scrum Master is to help the team remove the impediments they identify, and hence, the faculty mentor was able to transform impediments into learning opportunities.

At the end of each sprint were two consecutive meetings. During the *Sprint Review*, the team presented and discussed all of the potentially shippable products created during the sprint, and Gestwicki—again in the Scrum role of Product Owner—decided whether they adequately satisfied the corresponding user stories. Following this meeting was the *Sprint Retrospective*, during which the team reflected on its progress and its process. It is noteworthy that Sprint Retrospective meetings cultivate the metacognition that is necessary for effective reflective practice (Schon, 1983); it is partly because of this that previous researchers (ourselves included) have found modified Scrum particularly effective in teaching game design and development (Gestwicki, 2012; Schild et al., 2010).

Research Methods

The empirical data for this study come from the work of an embedded research team that conducted an ethnography during the full 15 week semester described

Figure 4. Sample task board created by Root Beer Float Studio to demonstrate its use of Scrum

above. Ethnography and other qualitative methodologies have a long and rich history in studies of learning, professional work, and design-related fields such as human-computer interaction and computer supported cooperative work. Our research protocol, therefore, was influenced by germinal ethnographic and qualitative work in these fields, especially Lave & Wenger (1991), Wenger (1998), Nardi (1996), Bowker & Star (1999), Spinuzzi (2003), and Lillis (2008), among others. In particular, our research protocol was strongly shaped by the analytic framework of activity theory, which explores not only intersubjective interactions, but the ways that such interactions are mediated by tools and symbol systems in culturally and historically situated activities and practices (see, for example, Vygotsky (1978), Leont'ev (1981), Cole (1985), Engeström (1990), Engestöm et al. (1999), and Kaptelinin & Nardi (2006)). Before moving to our description of participant design experiences, in the remainder of this section we detail our research questions, data collection and triangulation procedures, and data reduction and analysis procedures.

Our overarching research questions focused on the unique affordances of the immersive learning environment, and our ethnographic methodology gave us a granular, everyday understanding of learning and collaborative design at our research site. At the outset of our exploratory study, we wanted to know, quite simply, what stu-

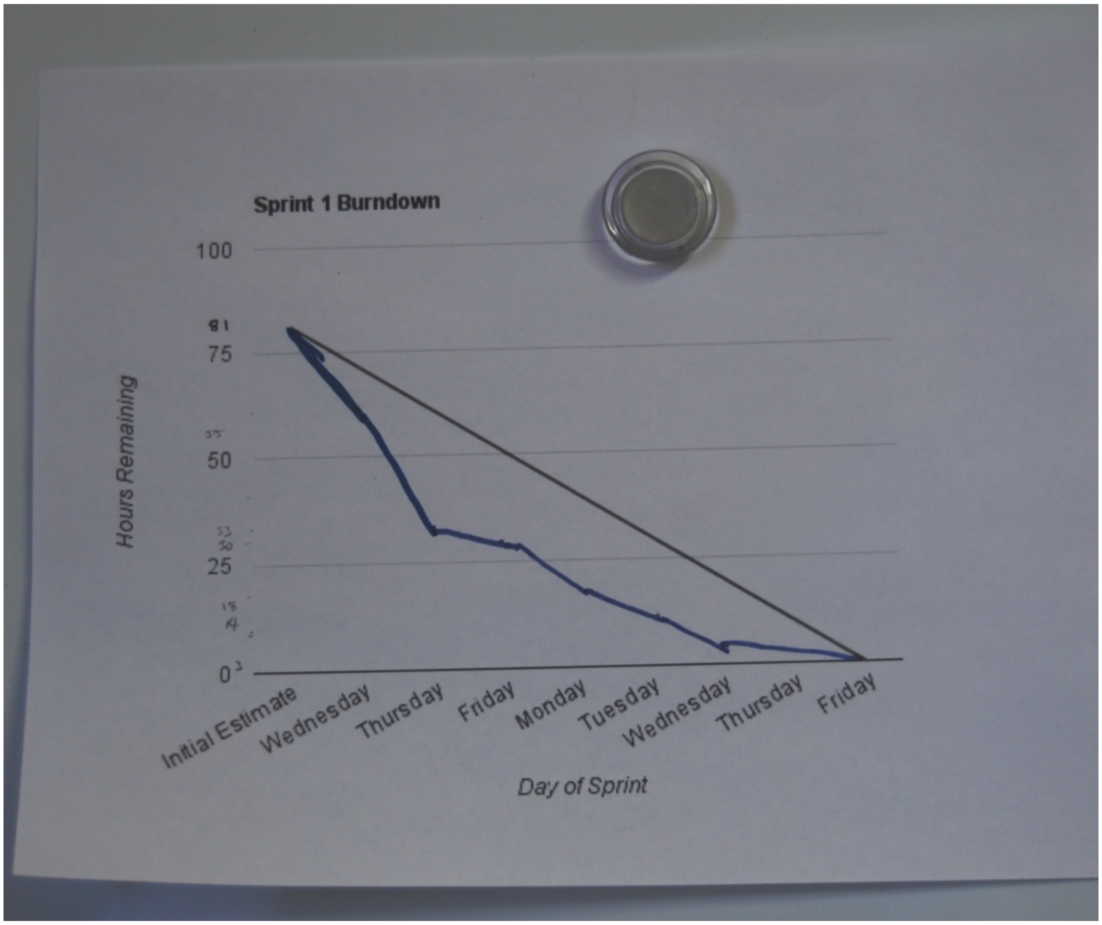

Figure 5. Sprint 1 Burndown Chart. The straight line shows steady progress, and the hand-drawn line shows actual progress, measured as totals task hours remaining.

dents experience in immersive learning environments, and whether that experience was qualitatively different from traditional forms of post-secondary education. More specifically, we were interested in the kinds of tool-mediated actions and intersubjective collaborations that could be traced through attention to writing, communication, and design practices during the immersive learning curriculum. Toward that end, this paper explores follow-on research questions regarding the impact of the five-phase design thinking framework on serious game design and development. In order to explore this question empirically, a team of four researchers conducted extensive fieldwork with participants, comprising 135 collective observation hours across 83 separate site visits over 15 weeks. (As PI, McNely led data collection efforts; Gestwicki had no access to data until after the semester had ended and grades had been reported). Our team collected multiple forms of data across multiple instances with each participant, giving us both a robust qualitative dataset and strong tacit understanding of everyday practices from which to base our claims. Our field work resulted in many individual data events across six major types:

Fieldnotes and Analytic Memos: our observations produced nearly 170,000 words of fieldnotes that were focused on both individual and collaborative practices, tool mediation, and participant lived experience. Additionally, we produced 24 analytic memos—reflections and syntheses of observed practice during the collection period.

Audio Recordings: we gathered 45 audio recordings of daily stand-up meetings, sprint reviews, sprint retrospectives, ad hoc collaboration sessions, and impromptu interviews.

Interviews: we conducted three rounds of semi-structured interviews with participants, focusing on how participants viewed their own practices and those of others, how they viewed their work in relation to traditional curricula, and how they used a variety of mediating tools in their everyday practice.

Photographs: we collected over 400 photographs during our study; these photographs were primarily used to document ephemeral and ad hoc writing practices.

Videos: we collected two videos of stand-up meetings and one video of pair-programming practices.

Artifacts: we collected over 150 participant-produced artifacts, including written documents, design objects, and images.

Our data collection efforts afforded well-triangulated insights about participant practices across multiple data events and through multiple spatiotemporal instances. Discussion of the full dataset is beyond the scope of this paper; instead, we rely primarily on fieldnotes, analytic memos, photographs, and a subset of semi-structured interview responses from each round of interviews (forming 493 paragraph-separated units), as detailed in Figure 6.

We selected these questions from the broader set of semi-structured interviews because they elicited participant insights that were directly related to issues in developing and executing design thinking dispositions. For example, the rather innocuous question from Interview #2—"Tell me about the 3/28 Museum Trip"—is contextually rich and nuanced, as we describe below. It was after this meeting with community partners that the team's design practice was brought into full relief; participant perspectives on this event, combined with observational data, yield insights into how our participants negotiated the significant challenges of serious game design in an immersive learning model. Questions about the Scrum project management framework, and about participant perspectives on design thinking and prototyping, provoked insights about the everyday practice of game design and development that were triangulated across fieldnotes, photographs, and analytic memos.

Following Strauss (1986), we rely on the ethnographic data detailed above to produce a substantive description of the Root Beer Float Studio participants and their

	Time Frame	**Selected Interview Questions**
Interview #1	2/22 – 3/1	How much interaction have you had with community partners to this point? How are you personally using things like the User Stories and other organizational notes (burndown chart, etc.)?
Interview #2	4/2 – 4/6	Is there anything particularly challenging or frustrating at this point? We asked about Scrum in our last interview; do you have any new thoughts about Scrum as a methodology? Tell me about the 3/28 Museum trip.
Interview #3	4/30 – 5/3	Give me your current perspective on design thinking, iterative design, and prototyping. If you were to do this all over again, what would you do differently, if anything?

Figure 6. Subset of semi-structured interview questions

experience as game designers. We discuss our observational data through 15 weeks of design—through everyday ideation, paper and digital prototyping, playtesting, and iteration of the prototype that would eventually become the studio's shipped game.

Fifteen Weeks of Design

The team met with The Children's Museum during the first week of the semester, and a result of this meeting was a list of six potential educational game topics. During the first sprint, the team created dozens of prototypes in order to narrow the design space. The second sprint was spent creating high-quality physical prototypes of the three most viable games from the previous iteration, and at the end of the sprint, one of these was selected for production. The game that was ultimately shipped was based on a design from the first sprint that was carried through the second. This design can be characterized by three phases of evolution that correspond to the three working titles of the prototypes: Photo Museum, Mystery at the Museum, and Museum Assistant. In the remainder of this section, we explore the evolution of this design through the semester, tracing the prototypes and processes that led to the final product. We recognize the complex, sociocultural, recursive, and iterative nature of design and do not mean to imply that the design followed a strictly linear path; however, attention to such nuances is beyond the scope of this paper.

Figure 7 provides an overview of the game mechanics that were incorporated into the design's three primary evolutionary stages. The salient features of each of these prototypes are described in turn below, with special attention paid to the relevant design thinking process phases.

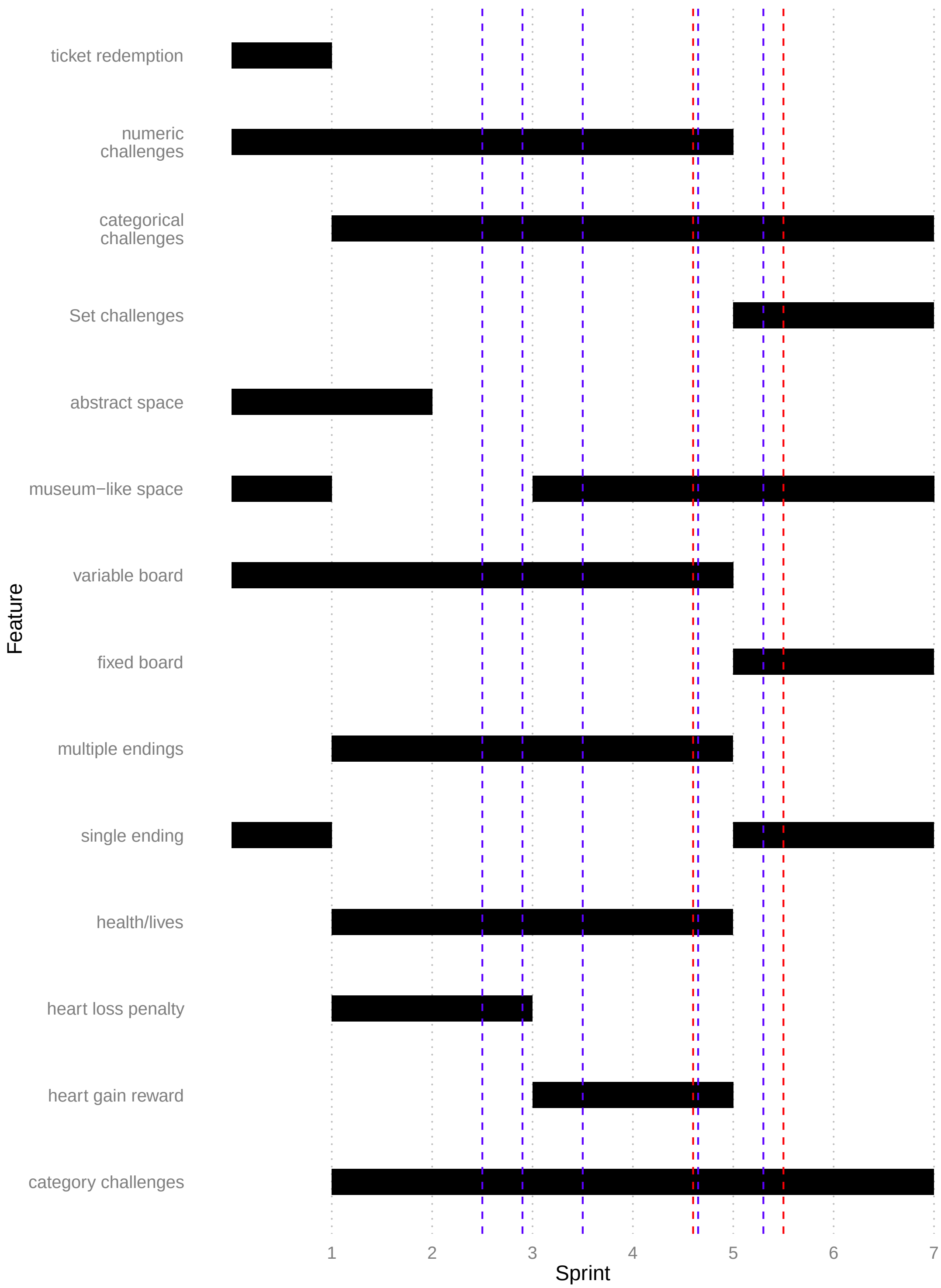

Figure 7. Selected game mechanics that varied during development. Vertical blue lines represent formal playtesting with end-users, red lines with the community partner.

Artifact	**History**	**Science**	**Art**
Microscope	0	2	0
Lincoln's Hat	3	1	0
Blown glass	0	1	3
T. Rex Skeleton	3	3	0

Figure 8. Sample artifacts from Photo Museum

Sprint 1: Photo Museum

During the first sprint, student designers created Photo Museum, a prototype in which the player explores a museum, using a camera to take pictures of artifacts on display. This ended up as one of the three prototypes that was selected to carry to the next sprint.

Taking photographs of artifacts framed the core gameplay experience. Certain artifacts were quantified by history, art, and science scores. When photographed in the game, some such artifacts were added directly to the player's inventory, while others initiated challenges: these were overcome by playing previously collected photographs whose total history, art, and science scores exceeded the respective values of the challenge artifact. Upon successful completion of such a challenge, a photograph of the new artifact was added to the player's inventory, and hence the game featured monotonically increasing challenge difficulty. Figure 8 provides an example of game artifacts; a player facing the T. Rex Skeleton challenge could play photos of the other three artifacts to overcome it. In the process, the player would earn "tickets," which could be redeemed for increased attributes or TF2-style hats (Valve Corporation, 2007). The designer identified *Betrayal at House on the Hill* (Daviau et al., 2004) and *Pokémon Snap* (HAL Laboratory, 1999) as primary inspirations for this prototype. As in Betrayal, Photo Museum required the player to draw randomly-selected tiles and arrange them to create the play area; as in Pokémon Snap, the player had a camera with which new collectibles were acquired, and managing these formed the core of the gameplay.

The design bears structural and aesthetic similarity to its inspirations. Playtesting was strictly internal at this stage of our study, and so the team members themselves had to act as both designers and user surrogates. It was not feasible for participants to work with real end-users at this point in the project, but the danger of basing decisions on user surrogates is well-known (see Constantine & Lockwood, 1999, for example) and was exacerbated by the team's inexperience. From the lens of our design thinking framework, we can see that the team found it challenging to balance empathy-building among the various project stakeholders. Early in the process, the designer was primarily considering end-users and our community partner, but after each round of internal playtesting, the influence of the team became more apparent. For example, tickets were introduced in response to internal playtesters' desires for increased complexity, but this decision was made without consulting end-users or the community partner regarding desired complexity level.

Sprints 2–5: Mystery at the Museum

During the second sprint, as two other concepts were being realized as high-fidelity physical prototypes, a small team of designers reshaped Photo Museum into Mystery at the Museum (MatM). In this version, the player takes the role of a child who is invited to an evening event at a children's museum. Upon arrival, the child is greeted by a camera-dwelling spirit who informs the player that the museum is haunted. A three-act dramatic structure is used in which the first act consists of the introduction and embedded tutorial, the second act comprises an exploration of the museum while overcoming small challenges, and the third act consists of a grander challenge and dénouement.

Whereas Photo Museum artifacts each had numeric history, art, and science ratings, the artifacts in MatM had a single integer value—knowledge power (KP)—an abstraction of the cultural and scientific importance of the artifact. This design decision sparked intense debate within the team, the suspicion being that young players would build inappropriately quantified mental models of artifact value, both for museums and more broadly. These suspicions were not validated against end-users or experts, and the KP kerfuffle passed when internal and external playtesting revealed that the game system produced the desired play dynamics: the players thought carefully about the artifacts they were photographing for their limited collections and how to curate the collection to overcome various challenges.

In addition to KP, MatM artifacts were classified with *themes*. The set of themes varied during the eight weeks this prototype was developed, and the final set consisted of Science, Computing, History, Fine Art, Pop Culture, and Architecture. Each artifact was classified by one or more of these themes. The taxonomy was developed primarily by the designers in order to balance the size and difficulty of the game, with parts of the taxonomy derived from Lord & Lord (2001). The team designed approximately thirty artifacts for the game, almost all of these coming from their imaginations—that is, not based on actual artifacts from the partner museum. This demonstrated a lack of empathy for actual curators that foreshadows the negative evaluation the prototype would receive by community partners.

Challenges in MatM were no longer linked to photographic attempts as in Photo Museum; instead, challenges were presented in each room after the first few. The presence of a challenge prevented the player from exploring further in the museum until it was overcome. Three kinds of challenges were designed: those that required an accumulated KP total, those that required playing a set or sequence of themes, and composites of these two. For example, the "Egyptian Technology" challenge was a composite challenge requiring the player to play 3 KP of artifacts using at least one Architecture artifact. Certain artifacts created synergies when played in sequence; for example, a photo of the *dracorex hogwartsia* fossil had 1 KP, but it earned an extra 1 KP if played after a Pop Culture photo (for the Harry Potter reference).

The early MatM prototypes had the player moving over an abstracted museum space as shown in Figure 9. That is, the board represented rooms of a museum but not a realistic museum floorplan. After Sprint 3, the game play area was modified to be more like a museum, as shown in Figures 10 (paper) and 11 (digital). Both the abstract and concrete layouts featured randomized room content except for a fixed lobby that provided the Act I tutorial area. The distinction between concrete and abstract spaces is significant for our discussion of design thinking. The use of an abstract space belies a lack of appreciation for the spatial constraints of museum collections and exhibits; the shift toward more concrete spaces represents empathy for the educational context and corresponding alignment with project goals.

The team spent significant effort attempting to revise the ticket system before realizing that it had more in common with arcades than museums. Once this contradiction was explicitly identified, the team was able to reframe the problem and decided to eliminate tickets altogether. That is, in evaluating the testing results, the team returned to empathy—considering what it was like to be a museum visitor—and decided to eliminate that feature.

Development of MatM involved four rounds of external playtesting with users in the target demographic (see Figure 7), and the results of this testing directly influenced the design of the game. An example can be found in the evolution of the player health system, which was introduced in order to give the player a way to fail a challenge, learn from the mistake, and try again without having to restart the game. The first attempt was framed as "battery power" that was drained by losing challenges and restored by winning them. The team noted that this was not the behavior of batteries and decided to retheme the health system as hearts, a well-established metaphor in video games. Initially, the player was given a full complement of hearts and lost one when losing a challenge, but external playtesting during revealed that using them as rewards—starting with only one and earning them as the player overcame challenges—provided the player with a better sense of accomplishment. However, further playtesting revealed that players began to care more about earning hearts than overcoming the challenges, representing the dangers of extrinsic motivation (see Kohn, 2011, for example).

MatM featured a hand-drawn cartoon style as shown in the logo of Figure 9. The color palette was subdued with dominant blues, purples, and greys, chosen to represent the evening setting and mysterious story. Original musical compositions further enhanced the mood. Playtesting revealed that players did not connect the color and music with the narrative setting; in fact, they were much more interested in exploring and collecting than in the story. Later digital prototypes incorporated an animated introduction sequence to reinforce the story, but the results of these were no different than the paper prototypes: gameplay trumped narrative for playtesters. With the aesthetic style, as with the health system, we see the team respond directly to end-user feedback, although without consultation with the community partner or domain experts.

Figure 9. Mystery at the Museum prototype with an abstract board

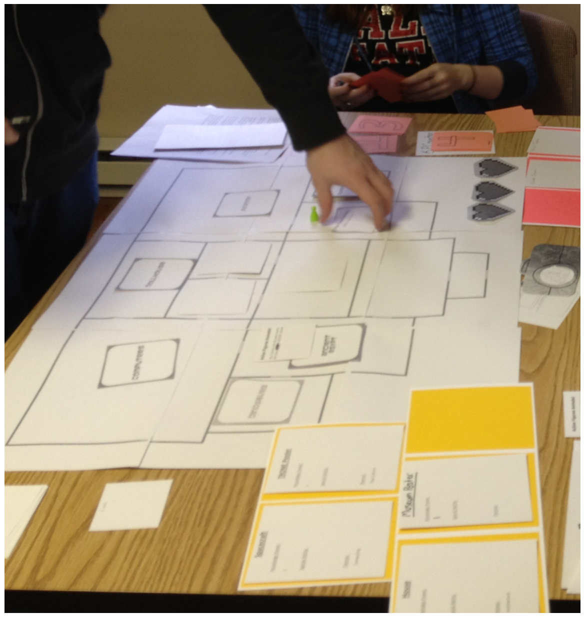

Figure 10. Mystery at the Museum paper prototype with museum-like board

Figure 11. Mystery at the Museum digital prototype with museum-like board

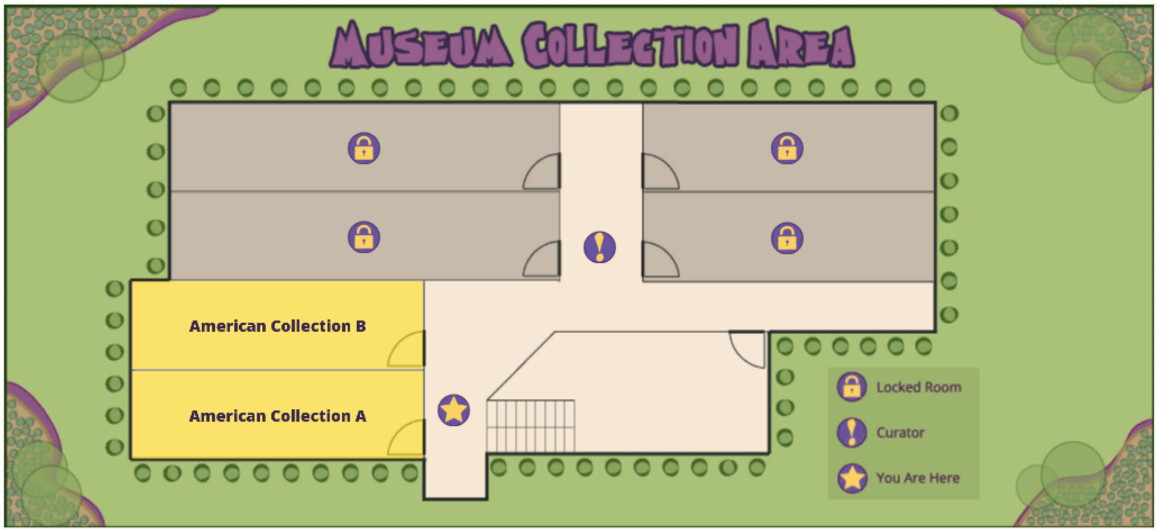

Figure 12. Museum Assistant map of the collection area

Sprints 6–7: Museum Assistant

At the end of the fifth sprint, the team demonstrated the digital prototype to the Children's Museum—the first time the group had shared a prototype with its community partner. Stakeholders from the Children's Museum helped the team to recognize many problems inherent to the design, the most important of which was that it did not clearly teach the player anything about collecting, curating, and museum operations. A secondary concern was that the artifacts were not related to the actual collections maintained by the museum. This feedback—combined with the results of digital playtesting that occurred the same day—led to a comprehensive redesign effort in the following sprint. Applying the lens of design thinking, the community partners were able to help the team realize that their ideation process was based on incomplete understandings of the end-users as well as the museum itself. That is, inadequate empathy led to ideation defects.

The comprehensive redesign effort during Sprint 6 resulted in Museum Assistant: Design an Exhibit, the game that was shipped at the end of Sprint 7. In this game, the player is a volunteer at the Children's Museum of Indianapolis. The player is tasked with creating digital exhibits based on actual artifacts in the museum's collection. As before, the player must overcome challenges to unlock new rooms, but the play space is now the collections storage area rather than the exhibit area (see Figure 12, and the challenges consist of creating exhibits for various curators.

In this version, KP gave way to a richer artifact taxonomy. Each artifact is characterized by three classifications, one for each of three categories, as shown in Figure 13. Figure 14 is a screenshot of the game, showing the player taking a photo of a chemistry set that is characterized as Modern Science from the Americas. Challenge mechanics are based on the rules of the card game *Set* (Falco, 1988), and an exhibit is made by playing three artifacts that constitute a set under these rules. When the

Region	Era	Type
Africa	Pre-1800	Art
Americas	Pre-WWII	Science
Eurasia	Modern	Toy

Figure 13. Artifact classifications in Museum Assistant

Figure 14. Museum Assistant: taking a photograph in the American Collections room

player succeeds in creating an exhibit, the game computes an appropriate name for it based on the artifacts within; for example, an exhibit containing one African toy from each of the time periods is titled, "African Toys through the Ages." Some challenges prevent the player from using certain types of artifacts, and others force the player to make an exhibit using a specific artifact; these nuances provide variation in gameplay and force the player to approach the game in different ways.

The development of the taxonomy in Figure 13 came from extended conversations with community partners about the actual collections and classifications used within the Children's Museum. The Museum provided photographs and organizational information on their various collections, and these became markers for the students' redesign efforts. Whereas previous iterations included internally-invented artifacts, nearly all the artifacts in Museum Assistant are actually in the collections of the Children's Museum of Indianapolis. This represents a dramatic improvement in the team's understanding of and empathy for the community partner.

In less than one week, a digital prototype of this game was created and shared, earning approval from the community partner. With this blessing, the team ceased formal external playtesting in favor of investing all of their resources into production and dissemination. Completing the game on time and on budget was made possible in part because the revised game design was much simpler, being constructed of fewer mechanics and more predictable dynamics and aesthetics (Hunicke et al., 2004).

Design Thinking in Practice

This substantive description of the design history of Museum Assistant provides insight into the design evolution and the significant events and feedback that impacted its direction. The decisions and observations described above emerged from practice-based research, and the team displayed awareness of these through formal reflections (such as team meetings and team member blog posts) as well as informal conversations. In this section, we revisit the role of design thinking in the design and development Museum Assistant. We offer empirically-derived findings about design methods for serious games, with specific implications for the learning context, the importance of meeting with and prioritizing opinions of stakeholders, the tension between horizontal and vertical slicing, and the place of iterative design and immersive learning in higher education.

Empathy for learning context

Many designers advocate user-centered design for conventional games (Fullerton, 2008; Schell, 2008; Schreiber, 2009, for example). Applying the design thinking framework, we would identify the player as a stakeholder with whom one should build empathy. In the particular case of serious game design, we find that building empathy for the learning context is at least as important. That is, a designer needs to build a rich understanding of the values and context of the learning objective domain. This resembles the argument for *usage* over *users* in human-computer interaction (Constantine & Lockwood, 1999, for example).

Support for this finding emerges from semi-structured interviews with participants triangulated across the design history detailed above, particularly during the MatM phase. Playtests with users in the target demographic could not identify design defects that caused misalignment with domain-oriented goals; this design blindness gave the team a false sense of security regarding their efforts. One of the team members describes this during the second round of interviews: "[We] were targeting ten year olds and … the content we had was for a ten year old, but our mechanics ldots they were for probably like 6–8…" She goes on to note that setting the difficulty level was an intentional decision by the team, but the community partners point out that the incongruity between artifact and gameplay complexity was a problem. This team member described her initial shock at the criticism: "playtesting went well, … it was a positive experience. And then the next day, when … the other part of the team came back, saying the Children's Museum didn't like it, I was like you've got to be kidding me! The playtest went well, right?" We see here that the team did not adequately build an empathy for the mission and values of the Children's Museum, and that by focusing primarily on playtesting results, they had made something that some players found fun but that missed key design objectives.

Meeting notes and interview data show that there was a particular criticism that was recognized and prioritized by the team: the use of inauthentic artifacts. Prior to this meeting, the team justified its invention of artifacts because they did not want to tightly couple the game to the Children's Museum. However, artifacts are the essence of a museum, and so fear that the community partner would reject their efforts led the team to make the overly-conservative design decisions that led to the rejection of the prototype. As one of the team members put it, "They want it to be about their museums, so, let's just dedicate ourselves to them and stop being so flippy floppy... They really got us back on track..."

Formal analysis of the game mechanics summarized in Figure 7 reveals that when the design thinking process was followed by participants, designs were aligned with goals. The design evolution reveals that nine of the game mechanics shared properties with real museums or museum visits, and all nine of these mechanics are present in the final game. Compare this to the nineteen mechanics that came directly from identified inspirational games (Daviau et al., 2004; HAL Laboratory, 1999), of which only six are in the final game.

Meeting with stakeholders spurs empathy-building

Each meeting with external stakeholders spurred the team toward empathy-building. This finding aligns with core principles of agile software development (Beck et al., 2001), which value face-to-face communication and for daily interaction of business analysts and developers. We see empirical evidence that this guides the team in serious game design and development, especially in meetings with playtesters and the community partner.

Playtesting sessions were always followed by discussion among those who ran the playtest and then by a formal debriefing to the entire team; these formal meetings were often complemented by written summaries of playtest results. These data reveal that playtesting forced the team to reconsider not just how the players will interact with the game, but who the players themselves are. For example, an early playtest involved a nine-year-old with reading difficulty; the team reflected on appropriate levels of reading—often invoking this particular playtester by name—during the rest of development. Even when playtests went well according to the team's heuristics, they still pushed the team to reconsider empathy for the players.

Meetings with the community partner also prompted renewed empathy-building. In the second interview, shortly after the Children's Museum meeting, one of the designers reflected on the role of their criticism to the process: "I wouldn't have thought of [these criticisms] myself but once they said them, a lot of what they said makes sense. It's really easy to think that the game makes sense when you're the ones who've come up with the idea and designed it." He goes on to note that "I know why we put [a feature] in there and I know how it actually works," but that hearing the community partner's criticism allowed him to gain new perspective and then, based on this, contribute to the redesign effort.

Community partner meetings also caused some relief among team members who lacked the confidence to voice criticism regarding the established design. One of the team members reflected specifically on the decision in MatM to use a dark color theme: "I'm glad they told us they thought it was dark, 'cause I didn't like it being dark. And, like they were saying a lot of things, that I in my head had a problem with, but didn't articulate, because I didn't want anyone to go off on me." This team member's perspective before the meeting is described: "I'll just keep rolling with this and everything right now because, I mean, it's okay and I thought maybe that at some point they would fix some of things later anyway." Evidence of the team's behaviors indicate that the art direction would not have changed without feedback from the community partner, as this feedback was necessary for guiding the entire team toward a unified direction.

Further evidence of empathy-building can be seen in a team member's reflection on being shown a newly-designed exhibit at the museum: "[They] told us a lot about how they chose, how to pull things together and . . . I think [this] could be helpful by trying to decide which artifacts we want to put into each room [of our game] because you kind of see what their point of view is. And they showed us what they do to make those decisions so that we can try to base what we're doing in the game off of that." We note that these comments reflect a rich, embodied, spatial understanding of the museum context in addition to the declarative, factual information regarding museum organization.

Tension between vertical and horizontal slicing

There is a tension between vertical and horizontal slicing with respect to the stages of our design thinking framework. A *vertical slice* is a build or prototype that incorporates elements of all the various layers of a system; it is also known as a *walking skeleton*, as it provides enough structure to engage in some critical application behavior but without being fully "fleshed out." For example, a vertical slice of Mystery at the Museum included a map, a set of rooms with artifacts, and representative challenges. A playtester could use this vertical slice to obtain a representative play experience, even if the individual components were not fully implemented, such as using a small map or diminished number of challenges. By contrast, a *horizontal slice* is a complete subsystem, and such a slice may not represent a playable unit. An example of a horizontal slice in MatM's design is the complete set of possible Act II challenges: although all of the details of the challenges are specified, there may be no mechanism for testing them in the absence of integration with Acts I and III. We note that vertical slicing is a beneficial practice in agile software development (Cockburn, 2007; Keith, 2010) because it allows for early identification of defects.

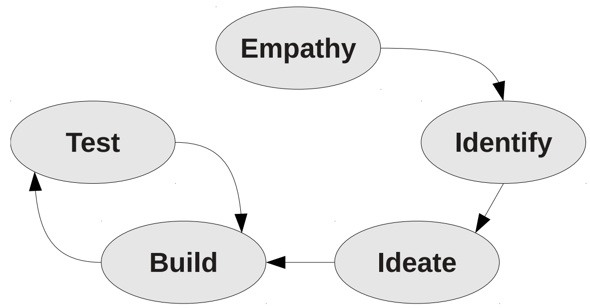

Figure 15. Short-circuited design thinking framework used for horizontal slices

We found that the team's design thinking framework was fruitful for developing vertical slices, particularly in physical prototyping. However, team members frequently applied the alternative framework shown in Figure 15, and this framework tended to lead the team towards horizontal slicing. We observed the subsets of the team beginning with empathizing, identification, and ideation, but the results of this third stage were interpreted—and sometimes recorded—as if they were specification rather than sketch. The team proceeded to build prototypes and internally test them. Upon passing these internal tests, the team returned to the de facto "specification" and continued building and testing with no regard for players or stakeholders.

We draw upon Mystery at the Museum for examples of how this alternate process was employed in design and development processes. In game design, team members invested days in developing a complete set of challenges for Act II without rigorous integration with the map, tutorial, or Act III challenges; validation of these challenges was left primarily to intuition, secondarily to intended but unplanned future integration testing. On the programming side, team members developed a complete technical subsystem based on the challenges, validating by inspection and automated unit testing. In asset production, collections of icons and buttons with focus and rollover states were produced based on user interface sketches despite minimal interface usability testing. Each of these cases demonstrates a particular horizontal slice, and in each case, all of the created artifacts were discarded—game design, source code, and art assets alike.

In an interview, one of the designers described how he sensed the tension between horizontal and vertical slicing and struggled to understand it: "… I'm still kind of fuzzy on the idea of vertical slicing. Like, I get it in theory, like I think you're supposed to just make a kind of good representation of everything rather than focusing on each individual piece, but … I can't get my head around how that compares to [Prof. Gestwicki] telling us that … it's not done until it's like production quality done. … I can't figure out how those two things work together so I never really understood that process."

It is noteworthy that this alternative design process is implicitly recommended by Test-Driven Development (TDD), a formal software development practice adopted by participants at Root Beer Float Studio. Test-Driven Development values tight iterations consisting of writing a failing unit test, making it pass, and then refactoring the code to a better design (Beck, 2002). These unit tests are technical constructs, orthogonal to concerns of usability or game design. In particular, TDD calls for programmers to create task lists superficially resembling the output of an ideation stage, but the TDD process suggests rapid articulation and action upon this list while limiting concern to the programming team. While usability and business logic analyses are frequently separated from implementation tasks in large software development firms, Root Beer Float Studio embraced Scrum's call for cross-functional teams (Keith, 2010; Schwaber & Sutherland, 2011), and many team members oscillated between design, implementation, and production tasks (as well as research, marketing, and management). Moving between game design and production processes likely contributed to inordinate investment in horizontal slices.

The team identified this phenomenon as problematic at the end of several iterations as well as the holistic semester retrospective. In the final retrospective, the value of vertical slicing was identified as one of the six most important learning outcomes of the academic experience. This suggests that the inexperience of the team may have been a factor in the observed conflict of horizontal and vertical slicing with respect to design thinking.

Iterative design challenges educational conventions

Root Beer Float Studio was comprised of undergraduate students in a unique immersive learning experience, and many students reflected on how the studio compared to their learning in more traditional curricula.. Most studio members commented that they expected the experience to be much more like industry than their previous and future academic experiences, and all of them stated preference for the immersive learning model. One of the team members described the contrast in the exit interview: "[N]ormal classes [are] not really set up for iteration… You're not meant to … fail the first five assignments and then you start getting better. You're kind of meant to, almost do a passable job and that's what [professors] grade you on…" He goes on to note that doing iterative design "has been difficult, but … obviously the end product is a lot better."

Another student noted that in conventional educational experiences, students are taught "to just take one pass at something" and that the attempt is evaluated based on whether "it lives up to the teacher's standard … or their predetermined solution." She identified iterative creative processes as her "biggest take-away" of the seminar, stating that she wants "to figure out how to apply iteration … in life and I think I'll be better off."

We found that following Scrum facilitated the team's adoption of—and competence with—iterative development processes. This is arguably the primary *raison d'être* for Scrum, and our finding provides empirical validation of its success (see also McNely et al., 2012). Artifacts (such as the burndown chart) and processes (such as the Daily Scrum) guided the team toward the creation of testable products. Further-more, when user stories specified that evaluation results needed to be collected and analyzed, Scrum guided the team towards timely completion of prototypes, scheduling of playtesting, and evaluation of results, and presentation of these evaluations in the Sprint Review meeting. This was true even early in the semester, when the entire team knew that the “potentially shippable products” they created were far from being shippable.

Concluding remarks

We have shown that the five-step design thinking model presented in Figure 1 provides a useful lens for designing serious games. Embedding the model into a fifteen-week design and development effort allowed us to evaluate the model via practice-based research, and this complemented a concurrent ethnographic study of the team. From this study, two features emerged as particularly important for serious game design: the emphasis on regular empathy and an iterative approach.

Empathy is known to be important for any user-oriented design process; we have demonstrated that it is especially critical for serious educational games where the learning objectives are inseparable from the domain. When stakeholders include both players and content-experts, regular meetings with both can help a diverse team prioritize feedback and build consensus. Identifying and articulating these priorities is paramount, as we have shown that emphasizing the perspectives of the wrong stakeholder groups can lead a team in unproductive directions. Conversely, building a better understanding of the problem domain—and the values of the domain experts—led the team toward effective designs. Evaluation of the finished game with other end users is an area of future research.

An iterative approach to serious game design was integral to the success of Root Beer Float Studio. Rapid iteration allowed them to explore a significant design space to identify shared goals, and then to transition a design through three different stages of evolution. The iterative approach was facilitated and enabled by both the team management framework (Scrum) and the five-step design thinking model, while the tendency toward horizontal slicing proved to be an impediment.

Finally, we note that immersive learning provides a unique approach for undergraduate education. The case history and findings demonstrate that the students engaged in deep, inquiry-based learning. Leading the students through metacognitive exercises such as Sprint Retrospectives resulted in their recognizing the value and distinctiveness of the experience. Immersive learning experiences can align with both academic goals and industrial settings, though longitudinal study is necessary to determine potential long-term impacts on the students.

Acknowledgments

We would like to acknowledge the contributions of Root Beer Float Studio to this work; without their willingness to take an academic risk, this experience would never have happened. Graduate Research Assistants Anne Burke and Bridget Gelms were invaluable in collecting data on the activities of Root Beer Float Studio. The Children's Museum of Indianapolis contributed significant time and attention to the seminar, and we are grateful for their collaboration. We recognize the generous support of the Edmund F. and Virginia B. Ball Foundation, without which these kinds of learning experiences and this kind of scholarship would not be possible. Finally, we thank the Provost's Office for their generous and direct support of the ethnographic study described in this paper.

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