Supporting Ecosystem Integration: Game-Infused Learning Trajectories for Teachers

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Statement of the Problem

There is currently a sizable gap in innovative, engaging, and high-quality products designed to support middle school students strengthen their writing and science skills in a manner consistent with the Common Core State Standards (CCSS) and NextGen Science Standards (NGSS). Literacy skills in the United States are failing to keep up with growth in other countries, with a third of 8th graders being proficient in reading and writing, and similar challenges exist for science. More generally, more than one million American students drop out of school each year – almost one student every 9 seconds. A primary reason youth cite for dropping out of school is a lack of engagement, due in large part to the perceived lack of relevancy of the school curriculum. To address these challenges, we need new curriculum models that excite and inspire our youth, not simply to remember or even apply academic content, but to foster in them a confidence and commitment to apply academic concepts to real-world problems.

This requires the creation of new curriculum based on innovative learning theory, and that is intended to position academic content, individual learners, and those situations in which the content has value as interrelated. Videogames in particular are being touted as providing a powerful learning technology with the potential to transform education (Barab, Gresalfi, & Ingram-Goble, 2010; Gee, 2003; Shaffer, 2009; Squire, 2006), with many educators, researchers, designers, and even industry partners working to develop new forms of game-based curriculum. Digital games are increasingly being used in education to help youth learn traditional school content and to foster 21st century skills, and even to build dispositional change as they develop a recognition for the real-world value of the content they are learning.

Games can make learning engaging, social, and relevant. Well-designed games and game-infused experiences offer a delicate balance of challenges and rewards that can drive deep levels of engagement and time-on-task, enabling players to advance at their own pace, fail in a safe and supportive environment, acquire critical knowledge just-in-time (vs. just-in-case), iterate based on feedback and use this knowledge to develop mastery. They enable players to step into different roles (e.g. scientist, explorer, inventor, political leader), confront a problem, make meaningful choices, and explore the consequences—even rewriting the narrative of the Self. Our theory of change posits that game-based experiences are most effective when treated as services (as opposed to products) that are integrated, managed, and continually optimized for ecosystem integration, ongoing sustainability and scaled impact.

In this symposium, we present data and insights from two of our student-facing games implemented with over 800 middle-schools students with low socio-economic status in a number of comparison studies. A core finding in this work was that having agency and consequentiality was a key learning value, and served to create a strong connection among player, content, and context. We also learned that we underestimated the challenges of eco-system integration, prompting us to focus on game-infused teacher professional development in the second year implementation. Consistent with our notion of games-as-services, in year two we situated our teacher-bounded games as part of a network infrastructure available to teachers that resulted in higher expectations for student learning.

Underlying Theory of Change

When it comes to using bounded games for supporting the learning of academic content, much of our work has been based on the theory of transformational play, a 3-fold theory that argues for the positioning of *person with intentionality*, the *content with legitimacy*, and the *context with consequentiality* (Barab, Pettyjohn, Gresalfi, Volk, & Solomou, 2012). The idea of transformational play highlights relations among the three interconnected elements of person, content, and context. In these games, learners become protagonists who use the knowledge, skills, and concepts of the educational content to make sense of a situation and then choices that transform the play space and the player—they see how the world changed because of their efforts. Such play is transformational in that it changes the context in which play is occurring, while at the same transforming the player and his or her potential to interact with the world.

In order to produce meaningful impact, we recognize the importance of situating these bounded game experiences within what James Gee (2013, personal communication) refers to as the Big "G" context. Big "G" game infrastructures are open-ended and seamlessly integrate the small "g" games into a larger, flexible 'meta-game' structure and affinity space that fosters user-driven extensions and adaptations in support of real-world goals and outcomes. Small "g" bounded games are self-contained and finite, pre-optimized to introduce, cover or re-enforce a particular lesson and well suited for learning in a safe, simulated and structured environment. However, it is with the Big "G" components (i.e., learning and management infrastructure, data and analytics dashboard, social communities and affinity spaces, achievement frameworks with gamification layers) that we transform individual experiences within a game into a dynamic interaction that extends learning beyond the fictional game world.

We view this as especially relevant when one treats teachers as a key component of the implementation infrastructure, and as having the potential to catalyze game-infused student learning within their classrooms. Therefore, a key focus in our work has been to develop game-infused professional development that includes a combination of bounded game and ongoing collaborative interactions with other teachers. Beyond the technical components, this has involved establishing an aspirational vision for student learning and positioning the games as one component of a larger teacher-owned implementation. Such positioning transforms the teacher from an individual responsible for following our procedural rules to an agentic and empowered partner who is leveraging a powerful tool to realize a shared vision. This sort of positioning is consistent with Gresalfi and Barab (2011) who discussed the implications of different forms of engagement: procedural, conceptual, consequential, and critical engagement.

Relevant to this study is the distinction between *procedural engagement* (using procedures accurately but without a deeper understanding of why one is performing such procedures) and *consequential engagement* (recognizing the usefulness and impact of disciplinary tools; that is, being able to connect particular solutions to particular outcomes). When students are engaging consequentially, they are able to move beyond rote understandings to apply their ideas. This notion of shifting learners, whether students or teachers, from procedural engagement to consequential engagement, is consistent with our belief that the latter is more likely to cultivate the underlying dispositions or "ways of being" necessary to thrive in the real world—not simply on the one we designed for them. Learning innovator John Seely Brown (2014, March) has argued that we "teach knowledge, mentor skills and literacies, and cultivate dispositions." With respect to cultivated dispositions, or ways of being in the world, at the core of our work is an ***engaged and purposeful learner*** who is open to new experiences, curious how the worlds works, and excited to lean-forward and take on personal, community and even global challenges.

More specifically, the intent of these designs is to support the cultivation of an engaged and purposeful learner with the more disciplinary-specific emphasis on being a ***disciplined investigator*** who is motivated to understand how the world works through quantitative and qualitative analysis. Additionally, for both the student and the teacher, we also wanted to cultivate the disposition of a ***persistent optimizer*** who is enthusiastic to persist past challenges, seeking out relevant feedback to continually improve solutions. Although Language Arts or science disciplinary skills and literacies were necessary for success gameplay, it was our belief that if we did not also cultivate an underlying disposition then the literacies would only be used within the defined context of the game implementation (or constrained assessment tasks), but not in those situations in which the task failed to overly structure how to apply the literacy.

Design-Based Implementation Research

In realizing this agenda, we adopted a design-based implementation research framework (Penuel, Fishman, Cheng, & Sabelli, 2012). Whereas some notions of design-based research have focused on how a design passes through theoretically-inspired translations and iterations across multiple implementations, we argue that from a research perspective it becomes difficult if not theoretically naïve to treat implementation contexts as separate from the design, an instead one must consider *designs as services* (not products) whose effectiveness is always integrated with how well the design engenders the ecosystem to optimize its success—fundamentally coupling design and implementation (Penuel et al., 2012). It is in this way that our notions of what we are designing and how they relate the ecosystems in which they will be realized has become increasingly complex and, potentially, transformative.

Here, we illuminate how we operationalized our theory of change through the implementation story of two-student facing, game-infused experiences and the subsequent building and implementation of a game-infused teacher professional development designed to position their engagement with the student experience in a manner that would begin to cultivate the broader dispositions mentioned above. The two student-based trajectories were first implemented in 2013 with ten teachers and over 800 7th grade students in a border-district with 90% having free-and-reduced lunch and a similar percentage being Hispanic—many of whom were English as second language speakers. Roughly, each designed trajectory involved 8 classes assigned the control and 8 assigned the experi-

mental condition, an equivalent curriculum unit that also lasted 2-3 weeks was created with teachers and we used a pre-test and post-test as part of two earlier studies on the games (Barab, Pettyjohn et al., 2012; Barab, Zuiker, et al., 2010). These games, along with the teacher facing games and professional network, were implemented in 2014 with the same teachers along with an additional 30 science and language arts teachers—making an additional 2500 students across both experiences.

Figure 1: Screenshots of the Doctor's Cure World (left), and the embedded essay submission tool (right).

Doctors Cure - The Doctors Cure is a 3D immersive game that positions players as protagonists in a virtual world where they must use their understanding of persuasive writing and how to gain evidence from complex texts in their role of investigative reporter. Inspired by Mary Shelley's novel Frankenstein, and set in a gothic world, students take on the on the role of a citizen reporter via their avatar, and complete a series of missions to uncover a moral dilemma involving Dr. Frankenstein's work. As reporters, students actively collect evidence through interviews and investigations, build logical arguments to support their theses, submit these to an in-game logic machine for evaluation, and get feedback about the alignment between their evidence and reasoning.

Figure 2: Screenshots of the Document Analysis Tool (left), and the persuasive argument analysis tool (right).

Players are intentionally positioned as agents of change whose purpose is to help the village of Ingolstadt decide if they should allow "Dr. Frank" to keep looking for a cure in spite of his questionable research methods. Players soon learn that persuasive writing is a necessary tool to resolve the game's narrative conflict. As the game progresses, players experience how their choices and use of persuasive writing dramatically change Ingolstadt, its citizens, and even the students' own identity as a writer and leader. In-game tools provide support in the interrogation of texts, as well as a model for testing the logic of their argument, and immediate feedback in the process. This design was implemented in an experimental design research study with 8 classes assigned the control and 8 assigned the experimental conditions—about 450 total kids with just over 400 completing both the pretest and the posttest. In terms of the 2013 implementation:

Results show that the both the treatment and the control conditions had statistically significant learning gains, and that there were no differences between groups for the multiple choice/short answer questions. However, when comparing the less-structured standardized essay prompt, there were significant differences favoring the eight treatment classes, with a large effect size.

- *Results also show that when asked why they were completing the current classroom activity, 74% of the students in the treatment condition chose "because I was interested in the task," as opposed to 22% of the control. In contrast, 75% of the control chose either "to get a grade" or "teacher told me to," while only 23% of the treatment condition chose this option.*

Differences in engagement and learning are credited to player agency, affordances of the embedded scaffolds, and the power of consequential outcomes. The fact that the experimental condition was able to perform higher on the open-ended writing prompt was particularly interesting because it suggests that these students were able to leverage the persuasive argumentation trope successfully in ways that the comparison students did not, even though they tested equivalently in terms of knowledge items. In both groups, however, teachers did not leverage the writing revision process, often accepting weak essays, and often let the game do the teaching as opposed to deeply managing the learning experience. Such issues speak to the importance of the platform integration and prompted the re-design of the unit with better collaborative tools a new pre-service teacher education game focused on feedback for student work. Additionally, we developed social network and community-engagement components, along with more achievement layers for teachers all with the goal of better supporting ecosystem integration.

Figure 3: Screenshots of the Taiga River Virtual World (left), and the scientific model analysis tool (right).

Mystery of Taiga River - The Mystery of Taiga River is a game-based science experience (water quality and scientific inquiry) designed with the goal of positioning middle school students as investigative reporters who must investigate, learn and apply scientific concepts (scientific investigation, water quality indicators, eutrophication, etc.) to solve applied problems in a virtual park, and restore the health of the fish without alienating various stakeholders. A core challenge in this work was balancing deep engagement in a game-based immersive world with the learning of scientific content. Players are positioned as agents of change, as water quality scientists, whose purpose is to help the Taiga National Park in uncovering the cause of the fish decline, a problem threatening the park's very existence.

Players soon learn that an application of science inquiry and systems thinking, coupled with understanding of water quality indicators, are all necessary to resolve the game' s narrative conflict. As the game progresses, players experience how their choices and use of science processes and inquiry dramatically change Taiga National Park, stakeholders, and themselves. As a form of embedded assessment, their chains are scored according to a pre-determined coding system, and they eventually learn whether: 1) they crafted the best chain of reasoning possible from the evidence at hand, and 2) whether the argument proves or disproves the hypothesis. Students use the constructed argument to write several scientific reports that are reviewed by the teacher. In the end, student choices determine the outcome of the river, with different students advancing arguments that result in different endings.

Figure 4: Screenshots of in game data collection of erosion (left), and a virtual fish tank experiment (right).

This design was implemented in an experimental design research study with 7 classes assigned the control and 7 assigned the experimental conditions—about 400 total kids were in the initial sample and 351 completed both the

pretest and the posttest.

- *Both the treatment and the control conditions had statistically significant learning gains, and when comparing the seven control classes with the seven experimental classes they were significantly greater for the experimental conditions with a large effect size difference.*

- *Qualitative analysis show different levels of engagement with the experience, and more first-person references in the experimental condition, and richer in-class discussions where students interrogated particular learning interactions.*

While the game demonstrated significant learning gains, students received impoverished feedback on their essay submissions and teachers did not make connections between the learning activities and supporting Common Core writing standards. Teachers also had difficulty managing the implementation, feeling somewhat alienated from peers, and used the teacher toolkit as a student management system rather than a place to inspire revisions and deeper engagement. This lack of cross-disciplinary fertilization, especially in terms of the Common Core Literacy Standards not being used to inform the persuasive arguments in science, prompted the design of a writing revision game for teachers, along with a game-infused professional network that pulled player score data and teacher review counts.

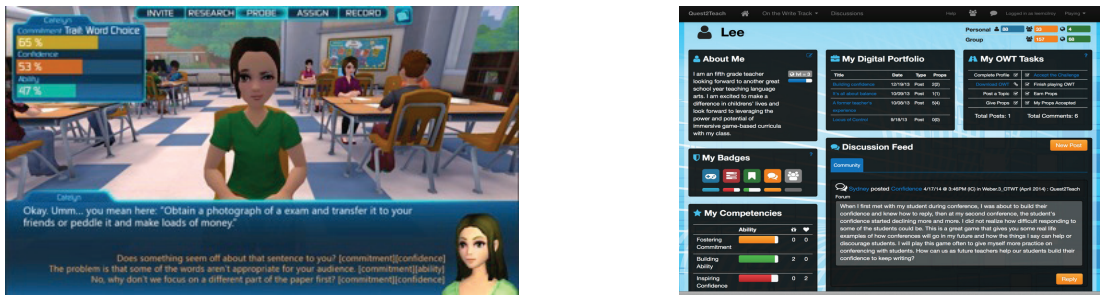

Figure 5: Screenshots of a teacher professional development game about student-teacher conferencing and support (left), and the integrated social network with meter fed from in-game activity (right).

Teacher Dashboard, Network, and Game Modules. Consistent with our notion of games as a service, the teacher dashboard allowed teachers to monitor student progress, access in-game student document summaries, identify key decision points for in-class discussion, and accept or reject student work. The dashboard allows for procedural management of student progress, but does not validate teachers for their hard work or allow them to network with other teachers. Based on a number of interviews and observations, and consistent with our broader theory of change, for the second round of implementation in 2014 we expanded the teacher offerings and connected these new features directly into the teacher dashboard efforts of the teacher. These designs were implemented in 2014 with the following goals:

- Creating a meta-game context around being a 21st Century teacher, emphasizing growth and participation as legitimate and supported;

- Acknowledging the amount of work teachers were doing in the review process, and connecting this into their social identity as a professional;

- Providing additional experiences with those skills and literacies that were essential to the successful implementation of the student experience;

- Shifting their role from a procedural one focused on student management to a more consequentially motivated focus on cultivating student dispositions.

The bounded game, On the Write Track, was adapted from the Quest2Teach project focused on pre-service teachers and implemented at Arizona State University. This game is an immersive world game where teachers conduct virtual Writers Workshop to provide students with critical feedback that inspires effective revisions of student work. The challenge is to ensure that the feedback identifies current writing weakness, but simultaneously increases ability, confidence, and commitment to revise. The virtual conferences begin with student-led sessions and then involve supporting students as they conduct a peer workshop, each of which results in scores representing the

virtual students' ability, confidence, and commitment to revise their work. Game meters and other in-game analytics are fed back into the real-world professional network, leveraging gamified achievement layers to validate and extend their digital experiences, via network of supportive colleagues.

In addition to game completion, the larger professional trajectory involves a sequence of challenges the player completes, including their online profile and accepting the commitment to evolve their practice, playing the game followed by the sharing real-world examples from which they can earn peer-awarded validation "props" that translate in-game achievements (meter scores from virtual characters) into a social currency to validate colleagues as they reflect, craft, and evolve their impact stories of how they are translating core learning concepts to the real world. The focus of this network is on supporting extended interactions and providing teachers with experience in collaborative learning communities focused on integrating game-infused strategies into classroom practices.

More than simply offering social and emotional support to transform teacher practices and shift conventional instruction, teacher communities provide technical and professional resources that encourage peers to work together and challenge each other. Therefore, a core goal has been to integrate professional networking tools and achievement layers to support a community that engages in collaborative sense-making and leverages bounded learning experiences and gamified achievement layers toward real-world professional growth and impact. To support more consequential engagement, we also used the network to create aspirational goals that positioned teachers to focus more on cultivating the larger dispositions, rather than simply focused on the skills and literacies or moving them through the game.

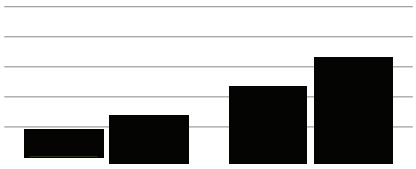

Figure 6: Change in Reports Accepted and Revised.

Our first round of implementation studies using the On the Write Track game and the broader professional network included teachers who participated in the 2013 study along with 30 additional teachers who signed up to participate for the first time in 2014 (total n = 28 LA, n = 15 science teachers). Preliminary analysis of teachers participating in both implementations focused on the degree to which teachers, on average, gave more feedback to their students in 2014 compared to 2013. Teacher feedback is expressed as the number of revisions per student teachers require of them as they progress through the game and the number of submissions that teachers accept. Findings illustrate that on average, students in 2013 were required to submit approximately 4.5 revisions based on teacher review of their work and that 1.5 submissions were accepted. In 2014, these figures increased to 6.5 required revisions with 2.5 accepted submissions—a 30% increase in required revisions and 40% increase in acceptances. The 2014 averages are consistent with teachers who implemented the games in their classrooms for the first time in 2014 and indicate it was not simply due to the previous year of experience with the games.

Summary

Across the two years of implementation we moved from bounded (small "g") experiences to building a rich set of experiences and infrastructure (Big "G") around the games, especially in the case of teachers. Consistent with this thinking, we further transitioned from a focus on games-as-products to games-as-services with a deep concern and commitment to supporting meaningful ecosystem integration. In terms of a design heuristic and visual representation of the argument, one might imagine charting player agency versus productive constraints on the y-axis and designed product versus on-going services on the x-axis. Here, one cannot relinquish responsibility for instantiating an expert model (whether it is underlying disciplinary literacies or the learning trajectory) to drive learning and engagement, nor can one ignore the power of player agency and local ownership of the implementation. The goal is not to position one's innovation too heavily in any one quadrant, and when properly designed one could even imagine a player's simultaneous experiencing of all four. However, in terms of a design and conceptual heuristic, the distinction has proven useful. Another useful shift in our thinking was from the treatment of a game as a bounded event to thinking more deeply about the surrounding Big "G" infrastructure, and the distributed learning trajectory through which players develop the literacies and dispositions.

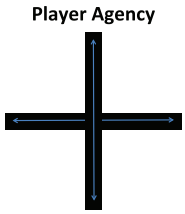

Figure 7: Design Tensions.

Our notion of a learning trajectory is consistent with the description put forth by Penuel, Confrey, Maloney, and Rupp (2013, p. 346), who describe it as "a researcher-conjectured, empirically-supported description of the ordered network of constructs a student encounters through instruction (i.e. activities, tasks, tools, forms of interaction and methods of evaluation), in order to move from informal ideas, through successive refinements of representation, articulation, and reflection, towards increasingly complex concepts over time." Given our interest in leveraging game-infused experiences and the importance of contextualizing these experiences as part of meaningful purpose, we translate this articulation into the concept of a Quest. A quest is a researcher-conjectured sequence of instructional challenges that leverage multiple modalities, diverse types of feedback, and a culminating "boss" deliverable to support an engaged and purposeful learner. While a particular collection of Quests might foster a specific set of literacies, across the various learning experiences it is the dispositions that orient one's actions towards particular ways of being that likely lead towards successful application of the underlying literacies.

Our work is now positioned to focus on building journeys that leverage multiple modalities and experiences, and that cultivate life dispositions. Toward this end, we have established a public-private partnership, and have built a journey-builder infrastructure with the goal of providing a cross-curriculum, game-based learning platform and community to help research-grounded, game-based-learning products make sustainable impact. In the case of the two student games introduced here, they are being revised and extended with supplemental materials and experiences to create rich learning trajectories focused on scientific inquiry and persuasive argumentation—as students who complete both trajectories will experience the power of specific disciplinary tools and literacies for addressing particular situations at the same time they gain an appreciation for the cross-disciplinary dispositions. The key walkaway is not what our specific platform will become, but to realize that games for impact must be built on a clearly articulated theory of change and with a deep appreciation for ecosystem integration challenges and opportunities if we are going to maximize the impact of this medium.

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