Undertaking an Ecological Approach to Advance Game-Based Learning: A Case Study

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ABSTRACT

Systematic incorporation of digital games in schools is largely unexplored. This case study explored the ecological conditions necessary for implementing a game-based learning course by examining the interaction between three domains (the innovator, the innovation, and the context). From January-April 2012, one in-service teacher learned and applied the Play Curricular activity Reflection Discussion (PCaRD) pedagogical model using the game RollerCoaster Tycoon 3 in a 5th and a 6th grade classroom to support student learning of systems thinking. Data sources included a knowledge test, interviews, and participant and video observations. The teacher (innovator) successfully adopted the PCaRD model (innovation) as a pedagogical guide for teaching systems thinking with the game in the school (context). Students had statistically significant gains in introductory systems thinking knowledge. Conclusions and implications are discussed for integrating games using our ecological approach.

Keywords

Game-based learning, Game integration, PCaRD, Ecological approach, Case study

Introduction

There is growing willingness among teachers and administrators to use digital games in schools (Millstone, 2012). However, despite the rising number of empirical studies that report an improvement in student academic achievement and motivation as a result of using games (Barab, Pettyjohn, Gresalfi, Volk, & Solomou, 2012; Kebritchi, Hirumi, & Bai, 2010), the evidence for it in many academic domains remains slim (Young et al., 2012). It has been suggested that research studies need to consider the dynamics of teacher intervention, social contexts, classroom environments, learning activities, and the alignment of the games used to facilitate an adequate understanding of the educational value of games (Young et al., 2012). This article reports results from a case study utilizing the Play Curricular activity Reflection Discussion (PCaRD) pedagogical model (Foster, 2012) in a K-8 private school over three months. We explored the ecological conditions of how a game-based learning course can be incorporated in classrooms through partnership with teachers.

First, a literature review on game-based learning is presented. This section also describes the rationale for undertaking an ecological approach to integrate digital games in schools and the theoretical framework adopted for the current study. Second, the research question and methodology are described. Third, the results section illustrates our ecological approach, highlighting the interaction between the participating teacher as the innovator, PCaRD as the game-based learning innovation, and the participating school as the larger context. Fourth, the concluding sections discuss the benefits of the ecological approach with PCaRD for the integration of games into K-12 classrooms.

Literature overview

Trends in game-based learning

Current trends suggest that many classroom-based game studies examine the effects of games on student achievement and motivation (Kebritchi et al., 2010; Papastergiou, 2009; Tobias & Fletcher, 2012). For instance, Kebritchi and colleagues (2010) examined high school students’ mathematics achievement after using the game Dimension M and found gains from pretest to posttest. Papastergiou (2009) assessed and found significant effectiveness of a computer game called LearnMem1 on high school students’ knowledge of and motivation to learn computer memory concepts.
Conversely, game studies conducted after-school focus their attention on interpreting the process of student learning through games (Foster, 2011; Squire, DeVane, & Durga, 2008). For instance, Foster (2011) used RCT3 and showed middle school students’ development of motivational valuing and disciplinary knowledge construction for microeconomics principles associated with operating a business. Squire and colleagues (2008) used Civilization III and showed how learning in games motivated disengaged high school students, leading to an interest in academic practices and development of world-history knowledge. Studies in both settings indicated the appeal of digital game-based learning for improving student learning and motivation; however, neither the in-school or after-school studies explored the role of classroom dynamics or teachers in these learning environments.

Some recent studies have indicated that teachers have the potential to augment the effect of games on students’ interdisciplinary knowledge construction and motivation to learn (Barab et al., 2012; Silseth, 2012). For instance, Silseth (2012) examined how the interactional episodes of one high school student with his peers and a teacher in a gaming context contributed to his understanding of the multifaceted nature of the Israeli-Palestinian conflict. Barab and colleagues (2012) described the role of one teacher facilitating two curricula (game-based versus story-based) on persuasive writing and its impact on student engagement with the topic. In both studies, teachers were knowledgeable about the game and used it as a resource to support students. Teachers performed several roles, which included (a) being an expert guide to help students navigate the nuances of the game and make connections with the learning objectives, (b) adopting multiple pedagogical approaches (e.g., instruction, discussion, observation) to invoke student reflection and provide feedback, and (c) aiding students to understand the relevance of their knowledge beyond the course.

Teacher intervention can be crucial in facilitating game-based learning; however, there is a lack of knowledge available in relation to the pedagogical processes involved in implementing games in classrooms (Hanghøj & Brund, 2011). Watson and colleagues (2011) showed that even when a teacher is knowledgeable about a game, a lack of systematic guidelines on how to implement games in classrooms results in game incorporation through trial and error, and assessments that do not fully capitalize on student engagement with the topic and the strengths of the game as a curriculum. Researchers argue that teachers need more holistic support if games are to be effectively integrated in academic courses in schools (Jaipal & Figg, 2009; Watson et al., 2011).

**Game Integration in Schools**

Extant literature has produced a list of factors affecting the integration of games in schools: (a) working around the daily school schedule and teachers’ pressures of content coverage (Baek, 2008), (b) ensuring that the school has a suitable physical and technological infrastructure (Ritzhaupt, Gunter, & Jones, 2010), (c) seeking training opportunities and administrative support for teachers (Kenny & Gunter, 2011), (d) identifying and adopting games that align with the curricular goals (Hirumi, 2010), (e) guiding teachers with appropriate game-based learning pedagogical models (Gros, 2010), and (f) supporting students with different levels of readiness to adjust to the use of games for learning in the school context (Rice, 2007). According to Ketelhut and Schifter (2011), there is a dearth of studies that jointly examine the effectiveness of employing digital games and its interaction with school conditions and implementers. The authors argue that these gaps should be addressed in order to facilitate significant digital game integration in schools.

One approach that considers some of the gaps identified is the Game-Network Analysis (GaNA) framework. GaNA was developed for enabling teachers in introducing game-based learning in classrooms by guiding them in game analysis and game integration within a curriculum (Foster, 2012). GaNA is a combination of the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) and the Play Curricular activity Reflection Discussion (PCaRD) model (Foster, 2012). TPACK provides a lens for game selection and analysis; that is, it helps teachers approach the game as a curriculum with constraints and affordances for technology, pedagogy, and content (Foster, Mishra, & Koehler, 2012). PCaRD is a pedagogical model that aids teachers in incorporating games in classrooms to achieve curricular goals and facilitate students’ engagement in academic domains (Foster & Shah, 2012). PCaRD includes the Inquiry, Communication, Construction, and Expression (ICCE) framework to foster transformative learning anchored in the game (Dewey, 1902; Shah & Foster, in press). Thus, GaNA provides the frame a teacher needs within their ecological context to focus on the pedagogy and content of games as well as the process to use and apply games in classrooms. In this article, we focus on PCaRD as a pedagogical innovation used by a teacher to teach a game-based learning course in a school context.
PCaRD provides a systematic pedagogical process that is flexible enough to accommodate and guide teachers in using games for teaching. Researchers (Foster, 2012; Foster & Shah, 2012) conducted a study supporting teachers and implementing the PCaRD model to facilitate students learning in mathematics and science. Results indicated significant student knowledge construction and the development of interest in the content. The teachers initially had little confidence, but commitment to use games. They became more confident and comfortable integrating games with PCaRD in a school with limited technological infrastructure and support. PCaRD served as part of an ecological approach for establishing the conditions for integrating games into classrooms.

**Ecological approach**

Scholars argue that technology adoption should be approached from an ecological perspective in which the relationships between multiple factors within the larger school context are considered (Nardi & O'Day, 1999; Zhao & Frank, 2003). For game-based learning, Klopfer (2011) has argued for an ecological approach to aid the practice of using games in a comprehensive manner, with consideration for realistic learning environments. An ecological approach is essential for adding relevance to claims made about the educational use of games in context. Thus, the authors adopted Zhao and colleagues’ (2002) ecological technology integration model.

Zhao and colleagues’ (2002) model consisted of 11 interacting factors grouped under three domains: the innovator, the innovation, and the context that impact the degree to which technology projects are integrated well in classrooms. Thus, in this paper, the conditions for using games in classrooms were established as follows: innovator—teacher in the classroom; innovation—PCaRD for game-based learning; and context—the school in the study (See Figure 1). We used all the 11 factors (Zhao et al., 2002) in considering the interaction between the innovator (teacher’s knowledge of technology, technology-teacher pedagogical belief compatibility, teacher-school dynamics negotiability), the innovation (its distance from school culture, existing practice, available technological resources, and its dependence on human and technological resources) and the context (human and technological infrastructure, and social support within the school).

This paper aims to emphasize that successful adoption of game-based learning requires an ecological approach. Such an approach is missing from the current studies, causing hindrances to teachers’ and researchers efforts at supporting student learning with games. The case study presented in this paper addresses these gaps in the field by (a) offering one example of the domains to be considered in undertaking an ecological approach, (b) ascertaining the effectiveness of our approach on student learning. Thus, the following research question was investigated, “What conditions are necessary in a satisfactory implementation of a game-based learning course for teaching systems thinking in a K-8 school?”

*Figure 1. Theoretical framework for determining conditions necessary for using digital games in K-12 schools*
Methods

An instrumental case study (Stake, 1995) was undertaken to examine the conditions necessary for game-based learning using an innovation – PCaRD, in partnership with an innovator - in-service teacher in a K-8 school - context.

Context and participants

In the spring of 2011, one female science and technology teacher with less than five years of K-12 teaching experience expressed interest in implementing PCaRD in her courses at a K-8 private school in a US Northeastern suburban city. As a Director of Design and Innovation at the school, the teacher’s goal was to develop and test programs focusing on higher-order thinking within a playful environment. Between the summer and fall of 2011, the teacher and the researchers created an introductory systems thinking course to support her students. In the winter of 2012 (January-April 2012), the teacher offered the course in a computer lab without change to eleven grade 6 students and ten grade 5 students for a total of 21 middle school students in two classes. All students (8 females, 13 males) completed the course. They identified as Caucasian American. These students averaged less than 2-hours of gameplay as compared to the US national average of 7-hours each week for children between 8-18 years old (Rideout et al., 2010).

Course description and goals

The goal of this course entitled ‘Thinking in Systems: a playful approach’ was to use games to teach systems thinking with the game as an example of a system. A system was defined as a set of interacting elements (objects, properties, behaviors, and relationships) that form an integrated whole with a common purpose. Whereas the game provided a platform to demonstrate system dynamics, the PCaRD methodology provided a structure for the weekly lessons for emphasizing specific aspects within systems. Additionally, course activities designed through PCaRD involved ICCE opportunities that allowed students (a) to examine how the elements within the chosen games fit together to form playable systems and (b) to learn how to apply the understanding of basic system principles to control the quality of interactions within systems. Examples of essential questions that guided the design of course activities were, “What is a system and how is a game a system?” and “What is the meaning of control and feedback in systems and games?”

The course was developed to facilitate students in developing the knowledge and skills in analyzing a system. Examples of knowledge types included, foundational-knowledge (e.g., feedback sources for assessing system efficiency), meta-knowledge (e.g., properties and behaviors of system parts to foster problem solving), and humanistic-knowledge (e.g., empathy-related decisions to manage a system). Example of skills included the ability to identify elements of a system, to understand the existence of several sub-systems, and to identify feedback effects in a system.

Data sources

Quantitative data sources included a 9-item pre-post knowledge test for systems thinking which was developed in partnership with the teacher based on the course goals. To aid in item construction, the researchers played RCT3 before the start of the study using the TPACK framework (Foster, 2012). The test included questions based on foundational-knowledge (e.g., identifying feedback sources), meta-knowledge (e.g., understanding the role of feedback), and humanistic-knowledge (e.g. negotiating feedback) about systems thinking in the context of the amusement park in RCT3 (See Table 1).

Table 1. Example of items from system thinking knowledge test

<table>
<thead>
<tr>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>What sources will tell you if your amusement park is making profit, efficient and successful?</td>
</tr>
<tr>
<td>Suppose new guests were not coming to your park, what could be the possible reasons for this problem?</td>
</tr>
<tr>
<td>What are the essential parts or elements that make up a good and a successful park? Identify at least 5 parts.</td>
</tr>
</tbody>
</table>

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Qualitative data sources included semi-structured (pre-course, monthly, delayed-post) interviews with the teacher. Some questions included “What is the role of technology in teaching and learning in your view?” “Please describe your teaching philosophy” “How appropriate is RCT3 for learning systems thinking in terms of content?” and “What are your insights about using PCaRD as you are implementing it?” Weekly in-class participant and video observations, and memos from after-class meetings were also maintained to gain insights about the overall development of the course, teachers’ emerging proficiency of integrating PCaRD through RCT3, and the overall fit of the project in the participating school context. Pre- post- and delayed-post interviews were conducted with students to further the researchers’ understanding of students’ knowledge construction, motivational engagement with systems thinking, and their experience in a game-based learning course using PCaRD. Examples of interview questions included, “What did you pay most attention to while building, designing and managing your park? How did that affect the success of your park?” and “What did you like about this game-based class?”

Game environment

Students played RCT3, a commercial entertainment CD-ROM single-player simulation strategy game. It is an interdisciplinary game in which players are allowed to experience a career in building and managing an amusement park within numerous scenarios (See Figure 2). The game was selected based on prior work (Foster, 2011, 2012) and its relevance to the content area in this study.

RCT3 exposed players to the systems thinking concepts in the context of managing an amusement park. For instance, players navigate between a birds-eye view and a street-view of their amusement park as they become engaged in different sub-system activities such as building rides, hiring staff, managing finances, attending to the needs of the park visitors, and monitoring overall park activities. Players were required to satisfy predetermined objectives (e.g., attaining a certain park rating) using finite resources (e.g., money, space) in order to progress. Objectives provided an overarching focus to player’s actions and guided them towards discovering the many system variables and their interactions in managing their park (See Figure 2).

![Figure 2. A screenshot from RCT3 indicating scenario objectives, player actions, and feedback](image)

Procedure

Over one term, the researchers worked extensively with the teacher, coaching and modeling to apply PCaRD to teach the course. This included supporting the teacher through face-to-face meetings and online-communication in integrating PCaRD as she planned her lessons. Furthermore, a researcher was present throughout the study to offer in-class support. Teacher-researcher meetings were held after each lesson to reflect on the significant occurrences for the day, to discuss concerns with the PCaRD implementation, and to plan for the forthcoming lesson. Lastly, the researchers encouraged the teacher to increase her familiarity with RCT3 (before and during the intervention) through game analysis around technology, pedagogy, and content for systems thinking.
The weekly course was offered for 90 minutes each for 5th and 6th graders. Typically, the PCaRD session began with naturalistic game playing (30-40 minutes), allowing player-game-peers-instructor interaction. Curricular activities (20-30 minutes) followed, in which the teacher used the game and students’ play experiences as an anchor to develop problem-based activities for achieving course goals. Prompt-based reflection (10-15 minutes) followed, in which individual students articulated how they applied their academic and personal knowledge to progress in the game. Closure to the session was brought by a discussion (10-15 minutes) in which students reconvened as a large group to express their opinions, seek explanations to their questions, and learn to make connections with the systems thinking concepts. Additionally, the teacher would address overall learning goals based on her observations of what was learned and what needed more attention. Each phase within PCaRD built upon the other to scaffold students’ learning experiences with opportunities for ICCE. Lastly, every PCaRD session was designed based on insights gained from the previous session and the curricular goals of the forthcoming week.

Data analysis

Match-paired t-tests were used to measure the change in students knowledge about systems thinking. Student interviews were analyzed using grounded theory (Charmaz, 2006) to understand their knowledge construction (foundational-knowledge, meta-knowledge, and humanistic-knowledge) and motivational engagement with systems thinking, and experience with PCaRD. Classroom observations, interviews, researcher memos, and curricular materials obtained from the teacher were also analyzed as part of the case study to document evidence satisfying and indicating the interaction between the three domains: the innovator (the participating teacher), the innovation (PCaRD), and the context (the participating school). In particular, the researchers examined the teachers’ understanding of (a) PCaRD as a pedagogical guide to implement games in classrooms and the school context, plan instruction, and support student learning (b) RCT3 as a curricular tool with its constraints and advantages for teaching systems thinking. This allowed in the triangulation of data to inform the results.

Results

We present the results in three sections to illustrate the ecological approach for addressing our research question about the conditions necessary in a satisfactory implementation of a game-based learning course for teaching systems thinking in a K-8 school. For instance, in the first section we describe the factors associated with the innovator for successfully integrating a technological innovation. This is followed by a description of the nature and extent to which the participating teacher satisfied those factors for implementing the game-based learning course. This is repeated for sections devoted to the domains of the innovation (PCaRD) and the context (the school).

The innovator (The Teacher)

Successful technology integration projects are closely related to the innovator’s comprehensive knowledge of the technology, adoption of technology that is consistent with her or his pedagogical beliefs, and ability to negotiate the social dynamics within the school (Zhao et al., 2002). As an educational technology, the game acts as a curriculum with inherent affordances and constraints in terms of pedagogy and content (Foster & Mishra, 2011) for facilitating students’ understanding in a given discipline. Therefore, in order to teach meaningfully with games, a teacher needs to acquire an understanding of students’ everyday knowledge including their knowledge of the game, knowledge about the pedagogical practices in the school, content knowledge, and knowledge which is specific to the game (e.g., relevant game dynamics, genre, specialized knowledge embedded in the game). The participating teacher believed that technology is a tool and its role was to transform learning. In an interview, she expressed her beliefs about using technology for instruction:

“…I am not using technology [because] I have an iPad or whatever, but if I think it will add another dimension. And I really think that [students] should learn a lot by doing things intuitively…than just you know just learning the equation. So, technology is very good when it brings more opportunities for intuitive learning.”
In addition, the teacher believed that RCT3 afforded students with hands-on experiences and a personally relevant context for learning about systems thinking. The game met her expectations of engaging students in intuitive learning about systems thinking:

“[Although] it is not obvious for kids to understand the relationship between parts in an amusement park [in RCT3]… I still think it is a very good way to teach systems thinking and to show them that even something like an amusement park is a system.”

RCT3 played a crucial role in accomplishing the course goals because it provided the basis for situating students’ learning of systems thinking. A well-rounded knowledge of RCT3’s potentials and limitations was also important for planning and implementing the course lessons using PCaRD, as the teacher understood that the relationship between parts in the game was not obvious:

“It is very important to [know] how the course goals can be mastered through the game. I had to make sure that all the concepts of system thinking that were part of my curriculum could be demonstrated through [RCT3] and that it provided added value to the curricular activity.”

The teacher’s knowledge of RCT3 evolved over the period of the intervention. As she increased her familiarity with RCT3 using different methods of game analysis (e.g., playing, observing, conversing) (Aarseth, 2003), she progressed from having a technologically functional understanding of the game, to being skeptical about the relevance of RCT3 to support students’ understanding of systems thinking, and finally gaining confidence in proactively identifying the potentials and overcoming the limitations of RCT3 for teaching systems thinking with PCaRD (See Table 2). PCaRD facilitated the connection between RCT3 and the teacher’s goals.

The innovation (The PCaRD model)

Several factors of an innovation influence its acceptance within the school: its distance from school culture, existing practice, available technological resources, and its dependence on human and technological resources (Zhao et al., 2002). In this study, the game-based learning course was implemented using the Play Curricular activity Reflection Discussion model (PCaRD), a technological and pedagogical innovation for aiding teachers in incorporating digital games in classrooms and supporting students in constructing foundational-knowledge, meta-knowledge, and humanistic-knowledge.

Table 2. Participating teacher’s emerging understanding of the RCT3 and the innovation (PCaRD)

<table>
<thead>
<tr>
<th>Phase of intervention/ Frequency of game analysis</th>
<th>Mode and focus of game analysis</th>
<th>Level of game competence acquired/ Resulting outcome(s)</th>
<th>Changing confidence about the game’s relevance for the course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to inception- Initial Weeks/ Infrequent</td>
<td>Game playing and observing a child play RCT3 at home</td>
<td>Basic operational/ Installing RCT3 on to the computers and resolving technical issues (e.g. creating special logins)</td>
<td>“RCT3 is an interesting game”</td>
</tr>
<tr>
<td>Initial Weeks- Middle of Intervention/ Occasional</td>
<td>Game playing at home Speaking with researchers Observing and conversing with students as they played Watching YouTube videos of specific game actions (e.g. ride building)</td>
<td>Limited knowledge/ Experiencing difficulties in integrating RCT3 while planning lessons and supporting students’ play.</td>
<td>“RCT3 does not provide the content for systems thinking. [RCT3] does not make it obvious for the students to understand the relationship between parts in an amusement park”</td>
</tr>
<tr>
<td>Middle of Intervention- Final Weeks/ Frequent</td>
<td>Game playing in the school lab Playing with specific curricular goals in mind (e.g. Playing RCT3 before introducing the concept of feedback)</td>
<td>Emergent knowledge/ Becoming aware of RCT3’s potentials and limitations in the context of the course</td>
<td>“RCT3 provides different feedback parameters to the player; however, you can play the game without paying attention to most of</td>
</tr>
</tbody>
</table>

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The teacher’s initial goal was to experiment with different approaches in game-based learning. Consequently, PCaRD was welcome within the participating school’s culture. Except for purchasing RCT3, the teacher did not have to request additional technological resources to use PCaRD. PCaRD also aligned well with the teacher’s pedagogical approaches. This was reflected in her understanding of the model, which developed organically as she implemented it (See Table 3).

As her comprehension of RCT3 and PCaRD deepened, the teacher became competent at incorporating relevant features of the game in her lesson plans and scaffolding student understanding during class. In one curricular activity, which focused on the topic of feedback, two types of feedback were first introduced: balancing and amplifying. Next, the teacher illustrated the feedback types using examples from students’ personal lives (e.g., sibling interaction) and school experiences (e.g., a game of basketball) – making connections with school content and student experiences using ICCE. Additionally, the teacher invited students to share examples of feedback, which were locally situated in their personal and school life contexts, and from their experience in RCT3. The teacher used a variety of contexts through PCaRD to introduce the concept before students were assigned to document the nature and sources of feedback.

<table>
<thead>
<tr>
<th>Month</th>
<th>Play</th>
<th>Curricular activity</th>
<th>Reflection</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>Students engage in intuitive and tacit learning</td>
<td>Students are provided with labels for understanding what they are learning They bridge the intuitive and conscious aspects of learning</td>
<td>Students translate their experience into words</td>
<td>Students expand their knowledge by sharing and learning from others experiences</td>
</tr>
<tr>
<td>February</td>
<td>Students experience flow as they interact with the game in a way where no one interferes</td>
<td>Students are introduced to the lesson goals through an activity. They acquire a specific focus</td>
<td>Students make the connection between what they learnt in the curricular activity and the play using the new terminology</td>
<td>Students become aware of their feelings and learning by reflecting individually They discuss and listen to opinions of others in order to learn from each other</td>
</tr>
<tr>
<td>March</td>
<td>Students engage with the game from their own natural curiosity and they interact with their peers</td>
<td>Students are engaged in an activity designed for addressing the essential questions for the lesson They gain a new set of tools to think with</td>
<td>Students use the newly acquired toolbox to make personal connections between play and curricular activity</td>
<td>Students broaden their perspective by being exposed to reflections of their classmates They gain insights for improving their own learning experience They tie their entire experience</td>
</tr>
</tbody>
</table>

After the completion of the course, the teacher summed her thoughts about PCaRD for supporting teachers and student participation in a game-based learning course in a school setting:
“[T]he use of PCaRD with its systematic approach was very useful when it comes to implementing video games in the classroom. Since this was the first time for my students to play a game in a learning setting – the structure helped them to see how the game is related to their learning, it disciplined them time-wise, and gave them an opportunity to share experiences. The advantages of the PCaRD model when using a game within a lesson is its ability to create structure when developing the lesson plan, helping with keeping the narrative throughout the lesson’s different stages and making the connection between one lesson to the next.”

The Context (The school)

Technology integration projects are affected by the human and technological infrastructure, and social support within the school. For teachers to capitalize on the affordances of game-based learning environments in schools, support needs to be provided across the context from school leaders such as principal, technology coordinators, and peers (Halverson, 2005). Using a game also requires consideration for technical and logistical issues such as the existence of appropriate hardware and software and sufficient access to it for the users.

The school culture facilitated instruction necessary for game-based learning and teacher development. There were few disruptions to the class schedule and technological infrastructure. There was support for teachers’ in developing expertise in implementing games using PCaRD. There was uninterrupted access to the computer lab and its resources. Students were also observed playing RCT3 in the computer lab during their free time.

According to the teacher, this was beneficial because students would come to the systems thinking course with additional insights for sharing with their peers during play and the discussions. The teacher also began playing the game during her free time. The lab was equipped with eighteen networked desktops and an interactive white board (Figure 3). Although an in-house technology person was not appointed, technical support was promptly available upon the teacher’s request. Few technical issues were experienced and were resolved in the first two weeks of the study. On several occasions, students’ saved games disappeared from the computers unexplainably. However, for most students, this provided an opportunity to start over and create an improved amusement park. Interestingly, the teacher indicated that the school principal had shown a keen interest to continue applying PCaRD in the following academic year with the involvement of additional teachers.

Student Learning

Both 5th and 6th grade students made statistically significant gains in the systems thinking knowledge test (See Tables 4 and 5). They developed a simple understanding of systems as a whole a set of interacting elements, as is visible in their descriptions provided during post-interviews.

Grade 6 students:
“System is how things work and how they make things work. Clocks, computers, our bodies are systems”
“A system is like a group of things that work together and contribute to one thing. In RCT3 you’d have rides, food stands, trees, employees to build an amusement park...and for people to have fun”

Grade 5 students:
“Can’t be one thing working by itself. It has to work like a team.”
“[Things are] connected. For e.g. bike is a system. pedal[ing] makes the wheels move”

Interpretive findings suggest that students found it difficult to see the personal relevance of systems thinking beyond the course. That said, at those grade levels, it was the intention of the teacher to introduce them to the concepts of systems thinking as preparation for courses in higher-grade levels.

<table>
<thead>
<tr>
<th>Source</th>
<th>N</th>
<th>PreMean</th>
<th>PreSD</th>
<th>PostMean</th>
<th>PostSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems Thinking Knowledge</td>
<td>20</td>
<td>14.80</td>
<td>2.60</td>
<td>17.50</td>
<td>2.98</td>
</tr>
</tbody>
</table>

**Note.** P < .01**, R² = 0.18**

Upon inquiring students’ experiences with PCaRD, students expressed their appreciation for the interactive nature of the class as opposed to passive instruction and grading based on abstract testing. Students also valued the chance to work on individual and group challenges during the curricular activities and believed that these activities fostered their creativity. Lastly, they shared instances where they used their insights from reflection and discussion sessions to improve their game play.

**Discussion**

This study investigated the ecological conditions that may be necessary in a satisfactory implementation of a game-based learning course for teaching systems thinking in a K-8 school. There was a good fit between the innovator, the innovation, and the school context- the three domains considered in the ecological approach undertaken (Zhao et al., 2002). The teacher’s strength as an innovator grew from her (a) pedagogical beliefs being consistent with the game used, and (b) her ability to reflect and improvise while implementing PCaRD, a systematic process she valued. The PCaRD model was developed as a systematic, albeit adaptive pedagogical guide to aid teachers interested in adopting game-based learning in schools, and it was characterized by low-moderate reliance on technological and human resources. Lastly, the school offered up-to-date technological infrastructure and encouragement towards offering an innovative course. Undertaking an ecological approach allowed overcoming the gaps identified in game studies (Papastergiou, 2009; Squire et al., 2008); that is, the approach aided in focusing on both the process and outcome of the game-based learning intervention on student learning and simultaneously its interaction with teacher roles and school dynamics.

Effective game integration requires educators to be able to decipher the relationship between a game, the achievement of curricular goals, and its fit within the school context (e.g., physical infrastructure) prior to and during its educational use. Our approach aided the teacher in developing a flexible knowledge of RCT3 in terms of its pedagogical affordances and embedded content for systems thinking in the context of its use (e.g., course goals, existing practices, middle school) (Foster & Mishra, 2011). Additionally, the teacher integrated her game knowledge with the pedagogical structure of the course- PCaRD (Foster & Shah, 2012), which adapted to the teacher and students’ emerging proficiency in the game-based learning course (Baek, 2008). Together, this aided the teacher in augmenting the effect of the game on student learning (Tüzün et al., 2009), and enhancing their motivation to learn about systems thinking by bridging students’ academic, personal, and game experiences (Barab et al., 2012).

When school leaders including administrative and teaching staff gain an appreciation for game-based learning, they can confidently adopt the challenge of innovating the learning environments in the existing school contexts. According to Owston (2007), teacher and student support of the innovation, teacher perceived value of the innovation, teacher professional development, and principal’s approvals are the essential conditions for sustaining a
classroom innovation. In this study, the participating school context was a private school and the principal was excited about the prospects of game-based learning for the students. The participating teacher, as the Director of Design and Innovation had more freedom to learn about and introduce an innovative course, an infrequent autonomy available to teachers (Kenny & Gunter, 2011). The school also supported the teacher with essential technical and logistic support, which is beneficial for integrating games in schools (Ritzhaupt et al., 2010). Although it is important that a successful application of game-based learning requires fulfilling the conditions proposed by Zhao and colleagues (2002), our approach is robust enough to be applied satisfactorily even when one of the conditions are not strongly supported (Foster et al., 2011). A game-based learning pedagogical model like PCaRD when applied holistically will facilitate success with commitment from teachers, administration, and students.

Implications and limitations

There are implications and limitation for our study involving the ecological approach for the use of games in classrooms and for learning. First, students did better in a post-test than they did in the pre-test, but learning is to be expected of any educational intervention. Qualitative evidence suggests student satisfaction was important in supporting their interest and knowledge gain. However, we do not have evidence of differences between this group and previous years where no video games were used for understanding the impact of the innovation. This study was exploratory. Thus, we recommend further research for developing a more conclusive understanding of the impact of this game-based learning ecological approach. Second, teachers may use PCaRD as a guide in the ecological adoption of game-based learning in schools. Since PCaRD is a part of larger framework, GaNA may be used as a guide to enhance a games’ potential as a curriculum, identify possible learning experiences to engage students in a subject area, and integrate the game systematically in academic courses to support students’ development of foundational-knowledge, meta-knowledge, and humanistic-knowledge.

References


