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FORMS OF LEARNING IN COLLABORATIVE VIDEO GAME PLAY

MATTHEW J. SHARRITT

Communication and Information Sciences, University of Hawaii
1680 East-West Road, Honolulu, Hawaii 96822, USA
sharritt@hawaii.edu
http://www2.hawaii.edu/∼sharritt/

Extensive literature has shown that games provide engaging, dynamic, and authentic learning contexts. An understanding of how learning takes place while gaming can inform the design of effective educational games and aid their integration into contemporary classrooms. This study used inductive methods to provide a detailed description of the use of video games for learning in a school setting. Results demonstrate that learning occurred across multiple levels and multiple granularities, and can be triggered by particular cues in the game or social environment. Characteristics of the most frequently occurring instances of learning are discussed. Results of this study suggest great potential for the use of games in education for learning, and can inform future game design.

Keywords: Games; video games; education; learning.

1. Introduction

Schools, especially at high school and college levels, are "still, to a large degree, structurally nineteenth century institutions" and "kids today are seeing more power-performance learning in their popular culture than they're seeing in their schools" (Foreman *et al.*, 2004, pp. 52 and 53). Games have the opportunity to provide authentic, intellectually engaging learning environments (Annetta, Murray, Laird, Bohr, & Park, 2006; Federation of American Scientists [FAS], 2006a, 2006b; Foreman *et al.*, 2004; Prensky, 2001; Shaffer, 2006; Squire, 2005; Stokes 2005; Zyda, 2005). Research shows that video games can provide a rich experience while providing game players the ability to navigate a virtual world, in which complex decision making and the management of complex issues might resemble the cognitive processes that they would employ in the real world (Ducheneaut, Yee, Nickell, & Moore, 2006; FAS, 2006a, 2006b; Squire, 2005; Stokes, 2005).

The literature suggests that games provide a rich learning context, in which gamer strategizing and the management of complex problems can foster creative thinking skills and show players how their decisions have dynamic outcomes (Squire, 2005; Stokes, 2005; Zyda, 2005). Games are engaging because they "give us

enjoyment and pleasure; give us intense and passionate involvement; give us structure; give us motivation; give us doing; give us flow; give us learning; give us ego gratification; give us adrenaline; they spark our creativity; give us social groups; and give us emotion" (Prensky, 2001, p. 144). Additionally, gamers can experience social learning through group membership and leadership situations in order to achieve goals within a game (Foreman *et al.*, 2004; Socially Intelligent Agents at CARTE, 2006; Zyda, 2005).

In a recent survey of over 319,223 students, 25,544 teachers, 19,726 parents and 3,263 school leaders in the United States, Project Tomorrow (2008) reports that more than half of students in grades 3 through 12 believe educational games would help them learn, and students in all grades (K through 12) average 8–10 hours per week playing games. Only 3% of elementary school students say they do not play games of any kind. While only 11% of teachers reported that they were already using video games in class, many teachers feel that games could increase student engagement, address different learning styles, and teach critical thinking skills. Over half of the teachers surveyed were interested in learning more about integrating gaming technologies, with only 6% of teachers saying that they saw no value in exploring games within education (Project Tomorrow, 2008, p. 4). While much research exists suggesting the benefits of using games for learning, more information is needed to understand how exactly that learning takes place.

1.1. *Research objectives*

Kirriemuir & McFarlane (2004) and the Federation of American Scientists (2006a, 2006b) discuss directions for research on learning with games. Much of the research that has been completed focuses on general introductions to gaming and their application in a classroom, broad case studies, and learning outcomes associated with using games in the classroom. There exists an opportunity for a thorough investigation into the actual uses of games in an educational setting. Kirriemuir & McFarlane (2004) discuss the need for further research that investigates collaborative learning in the use of gaming environments to support learning:

> The value of collaborative learning and the role of computers in promoting such activity have been thoroughly researched.... How this collaboration translates into a multiplayer gaming environment and how these environments might be used to support learning, remain some of the most interesting areas for potential further research and development. (Kirriemuir & McFarlane, 2004, p. 27)

According to Squire (2005), "it seems the important question is not can games be used to support learning, but how" (Squire, 2005, p. 1). While current literature on gaming in education discusses the ways in which games are used as learning tools in a classroom and their associated benefits for learning, much detail is left out on how students actually make use of the affordances provided by games in their learning

process through collaboration with peers and interaction with the interface to learn "through processes of discussion, collaboration and reflection on games embedded in peer team cultures" (Kirriemuir & McFarlane, 2004, p. 16). The objective of the research is to identify what learning takes place in collaborative video gaming. The present paper reports on the identification of instances of learning in the context of collaborative gaming. These results can inform future design, selection and use of games in educational contexts, and qualify future studies of game interfaces and student interactions with those interfaces. The study takes an open-ended, emergent approach drawing on grounded theory and ethnomethodology. The paper presents results on the actual use of games in a school setting to support the learning process by student dyads. The following research question is the focus of this paper:

> *In what ways does learning take place in the context of collaborative video game play by high school students?*

This question is addressed by completing a macro-level analysis that identifies major properties and categories of learning. Future research will examine the ways that students actually make use of the game interface and how they utilize their peers and mentors during collaborative game play, by focusing on the play-by-play of indexical actions during episodes of learning. Literature suggests that both peer collaboration and mentor guidance can encourage learning; and analysis will shed light on exactly how. A descriptive analysis of the use of video games in educational contexts can inform both game design and sound pedagogy: improving the game content and interface, as well as aiding in the design of instructional content and learning curricula.

2. Related Literature

Foreman (2004) discusses some benefits of games: they can be community building; encourage discourse and negotiation; are collaborative, so groups can co-think through problems (gamers can trade a controller depending on who's better at the given task; thus dynamically allocating resources); and can involve distributed, social decision making processes. Squire (2005) discusses an additional benefit of games: most games involve problem-based learning, where the learner has control of the flow and decision making involved in the learning. Problem based learning, as well as with most games, involves the learner being handed a set of tools or resources and then problem solving with those tools. Learners can find unique solutions to solve the problems presented to them, which promote creative thinking skills and dynamic resource allocation. "An interactive game can trigger profound insights for long-term thinking" (Stokes, 2005). These creative problem-solving skills may be a better preparation for tomorrow's jobs and economy, as well as a means of developing students' abilities to work through difficult problems.

Some students will prefer traditional instruction. Squire (2005) implemented the game *Civilization III* in his classroom, and noticed in his research that many

students were not used to learning by playing a game. Many students were overwhelmed by the complexity of decisions in the game. For instance, in *Civilization III*, students selected an empire of the past, and their decisions affected multiple variables such as politics, economy, social life and their military. Student learning styles may have been accustomed to the deductive, reflective style of traditional learning, where the game presented an inductive, active learning style. Some resistance to change in the classroom lies with the teachers themselves; more so in the baby-boomer generation and older, known as *digital immigrants* (Foreman, Gee, Herz, Hinrichs, Prensky, & Sawyer, 2004). Foreman suggests that *digital natives*, or the generations growing up playing video games, will be responsible for ushering in a new paradigm of learning with video games into school curricula and cultures.

An outcome of playing *Civilization III,* in Squire's (2005) study, was that students learned higher-order thinking skills such as strategic thinking, planning, and the management of complex variables. However, many students were overwhelmed by this complexity and preferred traditional instruction. Squire attributed this to a variety of potential factors: his students had never experienced anything like this before in other classes and were not prepared to learn in the new manner, and that they may have different learning styles due to their personal backgrounds and attitudes towards the type of instruction (similar to what is discussed in Hidi & Renninger, 2006). Most variables described need further research, but it is interesting to note that some variables might be manipulated (attitude towards games), while others cannot (such as predispositions toward games).

2.1. *Experiential learning*

Literature suggests that games can provide an environment in which higher-order thinking is encouraged. The Federation of American Scientists state that:

> Modern video games may develop higher order thinking skills, such as problem solving, strategic thinking, analysis, planning and executing, resource management, multi-tasking, decision-making in a fast-paced environment, and adapting to changing work scenarios. (FAS, 2006b, p. 1–2)

In addition, video games and simulations can change the nature of what is being learned. Games and simulations are by nature visual. Snir, Smith and Grosslight (1995) discuss simulations as a means to "give students the opportunity to witness or 'perform' experiments that might otherwise be too expensive, time consuming or too dangerous for them to do in the laboratory." Video games can provide a unique opportunity to experience and participate in active learning that would otherwise not be possible due to various practical considerations such as physical, time, budget, or financial constraints that may have previously limited teachers.

However, the gaming medium is not a magic bullet. Former games developed under the *edutainment* initiative attempted to create games to teach; however, the

word today has a negative connotation following its limited success. Many edutainment titles borrowed the gaming medium, thinking it was sufficient to create a fun, engaging learning experience. Game design focused on educational goals, with less focus on creating a fun, engaging game. Often, this resulted in games that students were less motivated to play: the game medium was used to entice students into doing something they considered boring. Traditional schooling was often simply transplanted into a game, rather than making a fun, playable game where learning was a byproduct. "Many educators contend that edutainment has largely produced shallow products focused on short-term test scores" (Stokes, 2005). Similarly, Chee (2007) discusses how "learning technologies are not 'good' in and of themselves" (p. 24), highlighting the importance of well designed game content and gameplay.

Stokes (2005) argues that educational game design can benefit from an interdisciplinary perspective, to bridge the gaps in expertise that may have existed in previous efforts. Chee (2007) argues that "educational games need to be designed in a manner that is guided by a deep understanding of pedagogy" (p. 24). While the design of educational games will benefit from these perspectives, many educational games are considered less enjoyable to play by students. Often, simply labeling a game as "educational" is enough to turn off kids from wanting to play them. Former efforts (such as edutainment) show the need for a balanced approach to game design that follows the success of commercial game design that keeps games both fun and challenging.

Most of today's schools favor standards-based learning, placing value on standardization (tests, homework, etc), obsessing over the memorization of facts. An alternative model of learning that makes use of games could be employed to take advantage of other kinds of learning that support creative thinking and problem solving. James Gee (2003) summarizes some of these benefits in his "36 Learning Principles" that highlight particular ways that well-designed games can support learning, and how learning and play have many of the same characteristics. Additionally, theories of situated cognition (Brown, Collins & Duguid, 1989) and situated learning (Lave & Wenger, 1991) could be leveraged so that learning is not abstracted away from the social environment in which it occurs and is used. In cases where direct apprenticeship and participation cannot occur, gaming might provide a virtual world for simulation of the environment.

2.2. *Motivation*

Regarding motivation, a well-designed game should do a better job of motivating game players to return to the game. Hidi & Renninger (2006) describe individual interest as "a relatively enduring predisposition to reengage with particular contents over time." The authors suggest a "Four-Phase model of Interest Development" which can help in educational gaming environments. These four phases are: triggered situational interest (a short term spark); maintained situational interest (a prolonged situational interest); emerging (less-developed) individual interest (a longer term, personal mind-state, with a supporting environment); and well-developed

individual interest (a long term mind-state, characterized by enjoying something very much). Hidi & Renninger imply that the earlier stages are characterized by affect; while the latter stages are more cognitive in nature (the person has an innate curiosity and wants to return to the subject).

Game challenges can both add or remove motivation for game players to keep playing. Ducheneaut *et al.* (2006) studied game data from the game *World of Warcraft*, a very successful MMORPG (Massively Multiplayer Online Role-Playing Game). The authors found an exponential relationship between the level number and the average time required for players to 'level-up' (go on to the next level). Graphing this created an almost perfectly exponential graph: as levels increased, an exponential increase in the average amount of time required to reach the next game level is reported. This sheds light on the very addicting nature of *World of Warcraft*, as it shows that the game's difficulty structure is designed almost perfectly. The authors hypothesize that either a too-difficult or too-easy leveling structure in a game leads to player boredom or frustration, while varying levels of difficulty are particularly annoying. *World of Warcraft*'s level structure is good at getting novices drawn into the game, and good at keeping skilled players motivated to continue playing. In addition, the slowly increasing level of difficulty keeps intermediate players from getting stuck too long on an unusually challenging level. An appropriate difficulty structure is one of many factors relating to a player's motivation to play a game.

2.3. *Identity development, investment and roles*

Gee (2003) discusses a *projected identity*, where game players blend their personal identities with those of the virtual identities of which they are controlling in games. Chee (2007) builds on this by describing this mixture of identities:

> The conflatation between real world player and virtual personal as they jointly enact a trajectory of experience through the game space creates a strong sense of projection into the game world, a sense of *being* (first-person embodiment) in the world as well as a sense of "being there" (embeddedness) *in* the world. This tripartite interplay of identities — virtual, real world, and projective — creates a powerful context for learning because of its dual active and reflexive characteristics. (p. 15)

Accordingly, game players can often choose among different in-game characters to create a desirable experience. Many games allow players to choose among characters with different characteristics and virtual identities. In many games, such as *World of Warcraft* described above, game characters have different roles and specializations within the game. The experience of game play and learning in the game can be considerably different based on the character chosen.

In *World of Warcraft*, players can choose characters from different characters, sexes, and classes, and can customize their appearance and choose a character that

suits their needs for playing the game. Each character set and class have different attributes, so the choice in a player's character determines much of their role in the game such as what missions are available, what social groups can be joined, and status within a social group. Forming groups of various identities can be useful in particular situations in the game where players can benefit from working on a task as a group, thus taking advantage of the variety of character attributes in order to succeed (Thomas & Brown, 2006). Characters develop a sense of their role and an identity within a group or 'guild' when they work together in a team. They can also teach empathy for other gamers as well as situational awareness (Ducheneaut & Moore, 2004). These social groups serve multiple purposes in the game: they are community building, they add to the sociability and communication done in the game, and form a 'virtual culture' within the game (PlayOn Project, 2007).

2.4. *Affordances and representational guidance*

Affordances, or potentials for action, are a relationship between an actor (in this study, students in a classroom) and an object (elements of the video game interface, peers, and the classroom environment). Originally, affordances were described as potentials for action by an animal in its environment, taking an ecological viewpoint of action potentials (Gibson, 1977, 1979). Later, human-computer interaction expanded the idea to discuss potentials on human interfaces, discussing both perceptible and hidden potentials (Norman, 1988). The study of affordances and game representations can be studied while examining learning in games, as they contribute and can frame discourse and activity within the game.

Suthers and Hundhausen (2003) discuss the role of visual notations, and how they can influence the ways in which we interact with software interfaces. Their work compared differences in collaborative discourse among those using software tools supporting the same task but through different notations (text, graph, and matrix-based). Their results showed "that the type of representations that learners use in collaborative investigations will impact the focus of their discourse" (Suthers & Hundhausen, 2003, p. 202). Collaborative work is influenced by the software tool in two major ways, most apparent in software constraints and in the salience of certain representations (Suthers, 2001). First, the tool limits the type of work or expression that is possible, as the software allows particular kinds of activity through its limited set of objects and potential actions (the software *constrains* activity). Second, the software makes particular aspects of the activity prominent, possibly while hiding others, through the choice of the software's visualizations. In other words, the representations provided by the software make particular interpretations more *salient* than others (Suthers, 2001).

With respect to educational game play, the design of particular game representations can similarly guide the discourse of students playing the games. Additionally, the design of representations within games might share similar salient cues to aid gamers in their interpretations. As mentioned by Oliver and Pelletier (2005), "it may be important to consider how representational cues can be used to indicate to

the player that distinct objects are of the same type (obey the same game rules) so that they will be able to transfer strategies learnt for one class of object to other related instances" (p. 12). The analysis of this study examines this notion: how both the tool (video game) can mediate the collaborative interactions of students, and how particular kinds of interactions are promoted by the design of the game visualizations.

2.5. *Methodology*

In the present study, an inductive inquiry is conducted to expose the actual uses of video games for learning. This approach is inspired in part by ethnomethodology, which attempts to gauge "what the group themselves are constructing as doing", looking closely at the construction of social order, from the group members' perspective (Garfinkel, 1967): As ideas began to emerge, the study adopted methods from grounded theory to help abstract patterns in the data and generalize to other situations.

Grounded theory is a sociological method that concerns itself with the "discovery of theory from data" that is not "based on a preconceived theoretical framework" (Glaser & Strauss, 1967, p. 45). This idea is referred to as *emergence*, as theories emerge from the data, rather than going into the study with a predefined hypothesis to test. Glaser & Strauss describe grounded theory as a "general method of comparative analysis" (p. 1). The researcher makes constant comparisons of ideas while studying the data: looking for themes or "theoretical categories" and constantly reevaluating those categories (taking advantage of replication to test those ideas). This re-evaluation is accomplished through *theoretical sampling*, or "the process of data collection for generating theory whereby the analyst jointly collects, codes and analyzes his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges" (Glaser & Strauss, 1967, p. 45).

Two specific methods of grounded theory were used in the methodology (from Charmaz, 2006): *Initial coding* is an initial process of iteratively looking through the data and applying short "memos" that describe/summarize segments of data. *Focused coding* is the generation of specific, initial hypotheses, describing patterns among segments of video data, which are further refined conceptually with iterative passes in the data until no new patterns emerge (categories are considered *saturated* when no new anomalies appear). These categories are conceptually organized (called *sorting*, highlighting relationships among concepts). A third method, *theoretical sampling* (a process of deductively testing generated hypotheses to see whether they hold up against new data) is left for future work.

3. Method

Three video games were selected for study and are discussed below. Games were played by dyads using a single computer. Two dyads, situated side by side, played each game, for a total of twelve participants. Each dyad played one of the games

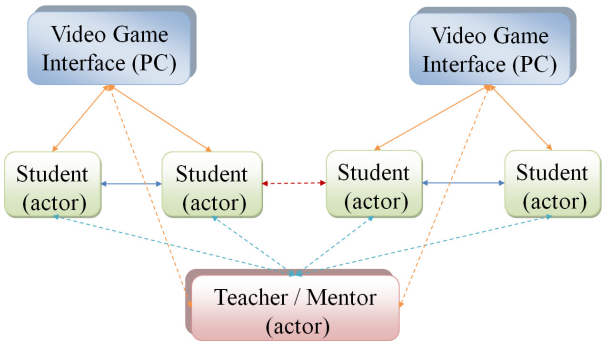

Figure 1. Study configuration.

for four study periods of approximately 50 minutes each, spread over four days. Figure 1 illustrates the configuration for each session. The lines illustrate the various potentials for interaction.

A complete video record was made of the game play. Data from the right hand dyads was analyzed for instances of learning. The logic of the study is the inverse of an experiment: rather than holding all but one variable constant to see what co-varies with that variable, the study varied the games and the participants to identify recurring patterns that can be postulated as inductive generalizations.

3.1. *School and student selection*

High schools were chosen and investigated for the potential to conduct research by interviewing teachers and administrative staff of the schools. Teachers at two high schools in the state of Illinois (United States) agreed to participate in the research. Teachers whose classrooms relate to the subject matter of the games were requested to participate in the study.

Student selection at the high schools strived to achieve a representative sample of students. Teacher assistance was used to gather students of various gaming experience and gender. Students were chosen based on willingness to participate, and willingness of their parents. Both student assent and parent consent forms were distributed to students, which were signed and returned to the researcher in order to participate in the study. Both the assent and consent forms were reviewed and approved by the Committee on Human Studies at the University of Hawaii at Mānoa.

When more than the minimum number of participants was available, selection was based on including variance of gender and game playing experience. A demographics form recorded student gaming experience, which varied among students playing each of the games. Different students were chosen to play different games: *RollerCoaster Tycoon 3* involved students from a related business course (Advanced Marketing), while *Making History* and *Civilization IV* involved teachers and students that had taken corresponding history classes.

The design of the study involved four students per game, playing in dyads. Literature suggests that group phenomena require three or more participants (Wiley & Jensen, 2006). Additionally, learning may also result from between-pair as well as within-pair interaction (similarly to what occurs in traditional classrooms). While difficult to seat two students per computer, the choice was made to videotape gameplay in dyads in order to elicit both collaborative and competitive behaviors among students, and to record the increased verbosity of students engaged in collaborative game play. Both the advice of the study advisor and experience from a pilot study indicated a large difference in the amount of discussion between students playing a game individually versus collaboratively in a dyad. Two dyads were used so that between-group collaboration could be recorded as well (similar to what might occur upon implementation of games in curricula, where an entire class of students would be involved). Students were allowed to self-assign themselves into dyads for collaborative game play. Having participants who know each other can be a benefit, so that collaboration is not stifled or overridden by the need to get to know each other.

3.2. *Role of the teacher and curriculum integration*

Teachers were not expected to have experience with the games being used. Students' questions were deferred to the teacher (when available) but were handled by the researcher when the teacher could not adequately answer the students' requests. While teachers in the study often did not pay much attention to the students playing the game, there were a few instances of advice related to the game's subject matter. A few times the researcher helped to resolve interface and game-specific issues with which the teacher was not familiar.

While much of the success of games in the classroom depends on active teacher involvement (Hidi & Renninger, 2006; Stapleton, 2004), the researcher avoided taking the role of the teacher in the study to avoid bias in the experiment. During the course of gathering data, the researcher avoided giving students guidance except specifically when asked by students or when technical assistance was needed with the computer or game interface, i.e., they reach an impasse.

In order to avoid classroom disruption and coordination problems, participating teachers were consulted as to when it was most convenient for their students to participate in the research. In some cases, students were asked to participate during a study period that corresponded to a time period that their teacher was not scheduled to teach. This helped avoid disruptions to the teacher's scheduling of topics and information presentation, as well as coordination problems with attempting to fit their class into a computer lab to play a game.

3.3. *Game selection*

A brief list of criteria helped in selecting quality games for the study. Games were chosen that were both fun and engaging, to elicit many of the properties of games as discussed in the literature review. Preference was given to games containing

quality graphics, gameplay and control, with a well designed and understandable game interface that would be expected in most contemporary games and contained a blend of entertainment and educational content (games that were rated both fun, and had subjects that were highly correlated with common school subjects). Games were sought that involved moderate levels of strategy development to encourage immersion and collaborative game play. Low computer hardware requirements were required, in order that the latest processors and 3D video hardware were not needed as schools are unlikely to have them. Games containing low levels of violence, foul language, or sexually themed content were chosen (ESRB rating of 'E' for everyone, age 10+). Based on the criteria, the following games were chosen:

Table 1. List of games chosen for study.

Game	Brief Description	Game Website
RollerCoaster Tycoon 3 (Atari) ESRB rating: E (Everyone)	Game player can build a virtual theme park; building rides and managing attractions within the park	http://www.atari.com/rollercoastertycoon/
Making History: The Calm & The Storm (Muzzy Lane Software) ESRB rating: E (Everyone)	Game player takes the role of a country in World War II and can play scenarios from that country; managing resources, etc.	http://www.making-history.com/edu/
Sid Meier's Civilization IV (2K Games) ESRB rating: E 10+ (Everyone 10 and up)	Game player can play an ancient civilization (Greeks, Romans, etc) and make dynamic decisions affecting their success compared to other civilizations	http://www.2kgames.com/civ4/

Three games were strategically chosen in order to compare similarities and differences among games of similar and different subjects, as well as similar and different kinds of games. Both *RollerCoaster Tycoon 3* and *Civilization IV* are *COTS* (Commercial-off-the-shelf games, created by large game corporations), while *Making History: The Calm & The Storm* was developed for educational use. Both *Making History* and *Civilization IV* are historically-based games (*Making History* focuses on World War II, while *Civilization IV* focuses on world history), and can be applied in world history or 20th century history classes. In contrast, *RollerCoaster Tycoon 3* could be applicable to a business course such as Economics or Marketing since it enables the creation of products and services, and the managing of finances (such as balancing supply and demand). Additionally, the three games varied in complexity, with *Civilization IV* being the most complex game of the three. This allowed generalizations to be made between COTS and games designed for educational use, between games of varying complexity, and between subjects (history vs. business) during analysis. This allowed inductive generalizations to be tested across these categories.

Figure 2. Data gathering of collaborative gameplay.

3.4. *Data gathering and timeline*

As shown in Figure 2, the primary data gathering tool was a video camera. Games were played on LCD monitors to prevent flicker in the video record. A wide screen video format was used to partially capture the heads and gestures of participants as well as the computer screen. Clip-on microphones were wired into the left and right channels of the video camera for quality audio recording of dialogue. The configuration shown in Figure 2 was replicated for each of two dyads for each gaming session.

Each of the three games mentioned were played over the course of four full school periods. Average class periods were approximately 45–50 minutes, and provided approximately three hours of gameplay per dyad (two pairs of students), per game (three games). A short group interview was conducted and videotaped towards the end of the last day of game play to supplement the gathered data and allow students to self-report on their experiences. Over the course of the four days, the majority of student dyads finished their games or chose to restart a new game; however, one of the dyads playing *Civilization IV* played the same game throughout (saved the game and continued the next day). This dyad might have used additional time, but by the final day they appeared to understand how to play the game well.

3.5. *Analysis*

The videos were imported into the Transana™ system, supporting Jeffersonian transcript notation,[1] for collaborative analysis by the author and his advisor. Analysis followed a hybrid qualitative research strategy that was initially data

[1]Described in: Jefferson, G. (1984). Transcript Notation. In J. Heritage (Eds.), *Structures of Social Interaction*. New York: Cambridge University Press.

driven and inductive, but then brought in theory for specific purposes. Data analysis was conducted in two phases, following with a discussion of results in comparison to existing theory.

- Phase I of analysis began by identifying what each dyad was accomplishing, and then identified learning episodes. Methods of grounded theory (Charmaz, 2006) were blended with a theory-driven approach to look for patterns among these episodes through the constant comparison and iterative sampling of episodes in order to describe patterns of learning.
- Phase II of analysis examines the affordances in each learning episode, and examines the sequential use and patterns of affordances in learning instances discovered in Phase I. Grounded theory methods are being re-applied to this level of description to seek regularities in the use of cognitive and social potentials for action during episodes of learning (reported in future work; analysis is in progress at the time of this publication).

The initial analysis sought episodes that evidenced "problematization" leading to "the production of understanding" (Koschmann *et al.*, 2005). Then, to collect a wider variety of learning episodes, episodes evidencing a change in behavior were gathered to increase the variety of episodes for further analysis that illustrate learning. Students' identification of a problem might mark the beginning of an episode of learning, and could complete when the problem is resolved; however not all learning episodes were this well compartmentalized.

Ethnomethodology and the principle of emergence guided the first portion of data analysis. Multiple passes were done examining each video, looking at what participants were "constructing as doing" (in line with the iterative, emergent analysis). Following, grounded theory's process of initial coding further developed the emergent hypotheses. Initial coding consisted of iterative passes on video data and attaching memos to video clips that exhibited learning, which qualified them for further analysis. Following the identification of learning episodes, further iteration through focused coding helped in sorting and saturating theoretical categories to create hypotheses based on patterns in the video.

In defining learning as "a change in behavior as a result of experience", almost any behavior could be considered learning. This fit well with the emergent approach, allowing the data to speak for itself. At the beginning of analysis, a preconceived definition was avoided in accordance with the ethnomethodological principle of *relevance* in our study. This principle avoids *a priori* definitions that may bias categories, stating that results should be produced as a direct result of observing participants' discourse and behavior (Garfinkel, 1967).

However, significant data reduction was needed, since approximately 24 hours of video were gathered. Video contained many instances of learning, as students were constantly exhibiting behavior changes through game play. The selection of learning episodes sought recurring patterns in the video data, and the most frequently occurring patterns of behavior change were selected for further analysis.

This selection of the most frequently occurring learning patterns limits the scope of findings and provides an opportunity for future work, but was necessary in order to perform a deep, descriptive investigation of the learning episodes (approximately 100 clips qualified, averaging a couple of minutes each).

4. Results

Our emergent approach showed that learning occurs on multiple granularities, at multiple levels, and can be triggered by both social and game cues. These three properties of learning episodes will be discussed following.

4.1. *Granularity of learning*

Initially, the analysis searched for learning in relatively short, well compartmentalized episodes that were initiated by problematization (Koschmann *et al.*, 2005). The idea of learning as episodic was useful as an entry into working with the data. Problematization allowed for the discovery of many instances of learning. In looking for episodes, the majority of episodes exhibiting learning were found using the problematization lens. However, it became clear during analysis that limiting ourselves to short episodes would leave out additional interesting forms of learning that appeared in the data. The concept of learning was broadened for the purposes of the study, and redefined as "any change in behavior" that was observable. This definition was a better fit with the theoretical stance as well as the data. Further analysis questioned the idea of episode granularity and showed that learning can occur at several different granularities.

Three granularities of learning were found: *short episodes* (as originally expected: marked by a problem and its resolution); *sequences of episodes* (episodes that were sequentially linked, often across spans of time; where a problem was marked early on and solved in a later episode); and *trends* (changes in behavior that appeared across time; often not marked by a specific problem and its resolution). Learning episodes were sought in Transana that illustrated all of these granularities, and were marked, tagged with keywords, and transcribed.

Short episodes and sequences of episodes often followed problematization where students discovered a problem and pursued a task, and was followed by the problem's later resolution (when the task was successfully completed). However, before describing the other conceptual categories, trends are discussed (following this introduction). Many trends are game specific, but show learning occurring over larger spans of time. Trends were often observed in a moderately used game feature whose complexity and use increased over time through the gradual acquisition of appropriate strategies. One example of a trend will follow, where students show a trend in learning diplomatic relations in *Civilization IV*.

4.1.1. *A trend of learning: Diplomatic interactions in civilization IV*

The research design of two dyads playing a single-player video game for four days had other computer-run civilizations competing with student players in the game.

As research participants advanced over time, so did their competition (other computer civilizations).

In *Civilization IV*, players take the role of an ancient civilization, and make strategic decisions on what technologies to research, what military units to build, what cities and economies to maintain, etc. Many complex decisions are made that result in the success or failure of their civilization. One of the very important aspects to manage is diplomatic relations with other civilizations. *Civilization IV* starts out in a primitive state with just a few people, and is a turn-based game. This means that decisions are made by the game player each "turn" (they have as much time as they want for each turn), and that they have to choose to end their turn after they have decided on everything they want their civilization to do for that turn. After ending their turn, the computer civilizations do the same (make strategic decisions and calculate moves for the turn). Each turn marks the advancement of time in the game and progress being made by civilizations (each turn represents a few years passing). As years progress in the game, typically civilizations become larger and more advanced.

Diplomacy with other civilizations is a key aspect that needs to be mastered in *Civilization IV*. Often, the game's computer-run civilizations will address the game players. At first, this often surprises the game players, as they are intently focused on their own civilization and then they are interrupted from what they are doing. Diplomatic interactions take the form of a large pop-up that fills the screen with the avatar of another civilization (for instance, the Greek civilization's avatar is 'Alexander', who wears a bronze chest plate, has a somewhat cartooned 'Greek' appearance, and has a building in the background resembling the Parthenon). The character is animated and his body language corresponds to his mood (for instance, if bad relations exist, he will appear angry) as in Figure 3.

The following episode transcriptions show a progression over the four days of game play by a dyad playing the game and illustrate a learning trend. Transcripts use Jeffersonian Notation (Jefferson, 1984), adapted from the Transana web site (Transana, 2008).[2] There are eleven episodes; following are excerpts from them.

The first interaction with avatars during the first day of game play surprises the students:

R: Press Enter.
L: ((*Presses 'Enter' on keyboard*))
R: ↑What?↑ ((*Trader window pops up*))[3]
L: 'I am (unclear speech)' ((*Reading from pop up window of a leader who has something to say*)) He's Greek.
R: He's gonna declare war against us.((*Laughs*))

[2] Adapted from *Jefferson Transcript Notation*, available at http://www.transana.org (Transana web site, 2008).

[3] "When another leader makes you an offer, you must choose to refuse or accept the offer. If you accept, the trade occurs immediately. If you decline, the other leader may ask you to make a counter-offer, may end diplomacy, or may declare war on you." (*Civilization IV* Manual, p. 101).

Figure 3. Avatar interaction in *Civilization IV*.

L: ((*Laughs*)) Oh.
R: We should probably -
L: We should probably go start building an army.

In the third line above, the right hand student is surprised by the avatar that has popped up in the game. Progress slows down as the dyad reads the new information that has seemingly come out of nowhere. As they realize it is another civilization with which they are competing, they strategize that they need to begin building up an army to deal with them.

The second interaction with computer avatars is initiated by the students. After realizing in the first interaction that they can talk to other civilizations, they begin diplomacy as follows:

R: Like, click on them, and see if you can do anything. ((*Clicked on Isabella avatar*)) 'Let's discuss something else' ((*Reading screen option in avatar interaction*))[4]

[4]This gives the option to discuss other leaders with the current leader that would like to trade. This game option can be beneficial when trying to figure out allies and enemies (for diplomacy, warfare, etc.).

L: ((*Clicks on 'Let's Discuss Something Else'*))
R: 'What do you think of' ((*Reading avatar interaction dialog/option*))
L: ((*Clicks 'What do you think of...'*))
R: 'Let's discuss something else' ((*Reading screen option in avatar interaction*))
L: ((*Clicks on 'Let's Discuss Something Else'*))
R: >↑Oh no↑<, go back. ((*Points to screen*)) Click (.) 'What do you think of'. ((*Reading screen option in avatar interaction*)) Can you type something in?
L: ((*Clicks on 'Let's Discuss Something Else'*))
R: Or no?
L: No. ((*Clicks 'Farewell' to dismiss avatar*))

The first user-initiated avatar interaction (above) is different than the first, which was computer-initiated. The dyad seeks out diplomacy with the other civilizations at the top of the transcript. Through the middle of the transcript, the dyad attempts to explore diplomatic options by trying out some of the things on the diplomacy interface, which can be seen in Figure 4. While the first episode draws attention to the game feature of avatar interaction, the second shows the dyad exploring diplomatic options that were afforded by the game interface, as if to gauge potentials for action (exploring affordances).

Later on in the day, the dyad was offered an item for trade, but decided to make their first major diplomatic act by declaring war on the other civilization. While this interaction was computer-initiated, the dyad continues to explore the affordances provided by the interface and try out some of the functionality by declaring war:

L: ((*Leader pops up to make a trade*))[3]
((*Leaders tradable items show on left side of screen, dyad's tradable items show on right side of screen*))
R: ↓We we can trade a pig.↑ ((*Scrolls over to dyad's tradable items*))
L: ((*Laughs*)) [°Barter.°]
R: ((*Scrolls over to leaders tradable items*)) [°What's expensive?°]
R: ((*Clicks through different items to trade*)) I, I want to declare war on someone.
L: Oh, go back.
R: ((*Clicks out of avatar screen back to main screen of game*))
L: And ah (.) hit you have to hit his name. ((*Points to the leaders name*)) ↑No not our name.↑
R: ((*Clicks on the avatar's name like L suggested*)) I did his name.
L: There.
R: ((*Leader pops up again*))
((*Clicks on 'Let's discuss something else'*))[4]

Figure 4. Trade and diplomacy interface in *Civilization IV*.

L: No. >There there.< Do it.
R: ((*Clicks on 'Declare War'*)) Look, look at this. ((*Prompt pops up asking if they want to go to war*))
L: Yes.
R: ((*Clicks on 'Yes'*)) ((*Laughs*))

At the top of the transcript, focus was on trading: the dyad seemed surprised that they could trade some pigs with the other civilization (remember, this is early in game play, and the civilizations are not yet very advanced). However, after exploring the interface, the right hand (R) person states that he "would like to declare war on someone". Because his request is non-specific ("someone"), the request is probably to learn of their strategic capabilities and the functionality of diplomatic acts, rather than a strategic move against a particular civilization that is interfering with their progress.

The next avatar interaction shows several changes in the growing complexity of the group's understanding of avatar interactions. First, another civilization has been discovered, raising the overall range of diplomatic possibilities (creating teams or alliances in the game). Second, the dyad attempts more complex trade offers

with other civilizations, attempting to trade resources in their proposals. Additionally, the dyad explores advanced treaties involving the trading of cities, which they deemed impossible after trying:

R: ((*Leader pops up asking to go to war*))
((*Clicks on 'Let's Discuss Something Else'*))1
L: ↑War! Do it. Do it.
R: ((*Clicks on 'What do you think about Isabella?'*)) No it's with Isabella.
L: Let's team up with him and then just (.) kill Isabella.
R: °'Now tell me what you think and be totally honest.'° ((*Reading from the avatar screen*))
R: ((*Clicked on Isabella's name*)) Just keep clicking on it.
L: No dude.
R: Hold on. ((*L tried to take mouse away from R*))
((*Clicked on 'Let's discuss something else'*))[4]
((*Clicked on 'What do you think of...'*))
L: Head off the war.
R: °No.° ((*Clicks 'Farewell'*))
R: ((*Clicked on Alexander the Greek leader*)) No. I didn't want to do that. ((*Clicks 'Farewell' on avatar screen*))
((*Goes back to main screen*))
((*Clicks on Isabella*))
((*Isabella pops up*))
((*Clicks on 'What would you like to trade'*))[3] 'Trade Proposals'
((*Scrolls over what Isabella has to trade*)) 'Declare war on Alexander.' ((*Reading a choice on Isabella's trade list*))
((*Clicks on 'Declare War' does not confirm*))[5]
L: Trade. To declare war?
R: ((*Scrolls over what the dyad has to trade*))
L: We have one gold. ((*Laughs*)) Whatever that means.
R: ((*Clicking through what the dyad has to trade*)) Well how do we offer stuff? ((*Clicking on every option the dyad has to trade with*)) Oh ok we can only trade gold?
L: Yeah. (.) ↑We can only offer tangible items.↑
R: ((*Clicks on all of Isabella's tradable items*)) Do you want (unclear speech) ((*Clicked on a city that Isabella had*))
L: No. You can't trade cities.
R: Why not?

[5] "The polite way to open hostilities" (*Civilization IV* Manual, p. 100), referring to a diplomatic war declaration. It is also possible to initiate a war without warning the enemy by invading their territory.

L: I guess you could but...
((*Clicks on 'Farewell' to exit avatar interaction*))

A few discoveries were made in the above episode: the potential to team up with other civilizations was available (the team found an option under "trade requests" to declare war on another civilization); and the students discovered some regularity in tradable items (they must be tangible things such as gold, products or even cities).

After earlier exploration of what Isabella had to offer, the dyad decided to allow "open borders" with Isabella (this allowed the movement of their people, items, and military across the borders of the other civilization without causing conflict). Additionally food resources could be traded between civilizations:

R: 'Let's make a deal.' ((*Isabella, a leader, pops up to trade; reads choices from screen*))
L: 'Open Borders?' ((*Reading choices from pop up window*))
R: Yeah. Tell them that's a good deal.
L: To do it?
L: We would -
R: °What are the current deals that we have together?° ((*Reading choice from screen*))
L: ((*Clicks on 'What are the current deals that we have together?'*))[6] ↓Nothing.↑ ((*Laughs*)) ↑Oh wait.↑
R: Open borders.
L: 'Isabella offers clam for wheat.' ((*Reads from screen*))
((*Moves mouse from over 'Trade Offers' to 'Farewell'*))
R: Yeah. (.5) °Say 'Farewell.'° ((*Reads choice from screen*))
L: ((*Clicks on 'Farewell'*))

A later episode demonstrates the discovery of more civilizations. As time unfolds in *Civilization IV*, the size of one's map grows (the map slowly uncovers itself as more territory is explored, as shown in Figure 5). In a later episode, a new civilization was discovered on a recently uncovered part of the map. Often interactions with new civilizations consist of learning of new items that they might have for trade. The dyad attempted to purchase open borders from the other civilization, which then came back with a counter offer: open borders for open borders (allows both civilizations to move across each other's land). The game players were beginning to realize that new civilizations are resources in the game that can be used via diplomacy (to gain new items, to gain strategic positions, etc.)

The next set of episodes demonstrates a growing complexity in understanding of the role of diplomacy. The dyad has been fighting a war with another civilization: Alexander (the leader of the Greek civilization). Alexander attempts to make a peace treaty with concessions early on in the war. The dyad was confident in their

[6] "Some 'annual' deals continue over time. This option lets you review any such deals you have in place with the leader." (*Civilization IV* Manual, p. 100).

Figure 5. World view in *Civilization IV*.

ability to destroy Alexander. The dyad makes a counter-offer: a peace treaty with concessions, which is high-stakes for Alexander. This makes him angry, and he rejects the offer. The war between civilizations continues for a while. Later, a second diplomatic effort by Alexander is rejected by the dyad. While the dyad enjoyed some early success in the ongoing war with Alexander (Greek civilization), the war had been continuing for some time and had drained the dyad of resources. The other civilization offered a peace treaty with concessions, a deal where the dyad would have to give the enemy some of their technology items. However, the dyad decided to reject the treaty in favor of continuing the war and keeping their goods. Still, a change could be seen because the war had been dragging on and draining resources.

A change in behavior could be witnessed in the next episode: after the war mentioned in the previous episode continued even longer, and the civilization became more drained by the war, a peace treaty with concessions was considered:

R: °Alright, lets this one° ((*Leader popped up for trade*))[3]
L: ↑NO.
R: Yeah. Dude they're going to kill ↑us. ((*Laughs*))
L: ↑Feudalism↑? ((*Points to what the dyad has on the trade table, Feudalism*))

R: Craig, they're gonna kill us.
L: ↑We're giving 'em↓ ↓our crap for ↓nothing dude!↑
R: ((*Clicked on 'Can we negotiate'*)) Give us the city.
L: ↑Tell him to give us Delphi↑. ((*Laughs*))
R: ((*A note from the leader popped up*))
((*Clicked 'Ok'*)) °Whaaa ha what?° ((*Offer rejected*))
L: ↓Whatever I don't care.↑
R: ((*Clicks to accept the original offer of a peace treaty with concessions*))
((*'We would like to make a proposal' pops up*)) °Where's the city?°
((*Clicks on the leaders city to trade*))
((*Trying to click on 'Declare War'*)) (.5) How do I declare war against someone? ((*Clicks 'Farewell'*))

Some negotiation occurred: one student did not want to give technology up for the peace offer, but ended up giving in after some convincing by his teammate. In the above transcript, a more complex understanding of diplomacy is displayed, as game players realized it may be the only way out of the war they have been fighting for too long. This furthered their understanding of the purpose of diplomacy: the dyad realized that giving away some technology is a better option than continuing to fight a war they might lose.

A final example from game play shows diplomacy becoming more complex, as other civilizations forced the dyad to choose sides (as the level of competition was raised towards the end of the game). One computer civilization requested that the dyad stop all trading (in effect, an embargo) with another civilization:

L: Ah, we would lose our Explorer. ((*Leader has popped up to start trading*))[3] ((*Clicked on offer that is on the table*))
R: No.
L: And we can't construct harbors.
R: No. Say no.
L: ((*Clicked on 'Farewell'*)) °Traitor.° ((*Isabella popped up wanting to talk*)) °'It can no longer be tolerated we demand that you leave the Egyptians'° ((*Reading what the leader has to say*)) What's our deals with the Egyptians? (.5) ↑We should probably cancel it because she's right next to us.↑
R: Yeah. Let's do that.
L: ((*Clicked on 'What do you think of...'*))
((*Clicked on 'Alexander'*))
L: 'Annoyed.' ((*Reading from screen*))
((*Laughs*))
R: ↑See if you can declare war with her.↓ Make a trade proposal. °No that's something else.°

L: ((*Clicked on 'Farewell'*)) Oops.
R: Click on ((*Pointed to Isabella's name*)) (.5) Isabella.
L: [Trade Proposal?] ((*Reading from list of options from trade screen of Isabella*))
R: [Trade Proposal?] Yeah.
L: ((*Clicks on 'Trade Proposal'*))
((*Items to be traded for both sides pop up*))
R: °Like declare war on her. (.5) Scroll down. 'Alexander'.°
L: For what?
R: Click on that.
L: What?
R: Click on 'What do you want for this'. ((*Choice on screen*))
L: ((*Clicks on 'What do you want for this' option*))
R: No what? ((*Isabella is shaking her hand and her head no*))
L: [Gold going up] ((*Clicked on their gold*))
((*Closed gold option*))
R: [Gold going up] 'Can you trade this for a good friend?' ((*Points to option on Isabella's trade screen*))
L: ((*Clicks 'Can you trade this for a good friend?'*))
((*Isabella shakes her head no and her hand no*)) I don't know what we're doing.
R: Ok never mind. Go back to. ↑Try to declare war.↑
L: ((*Clicked on 'Farewell'*))

While the dyad explored more diplomatic and trading options in the latter part of the episode (learning more advanced trading skills continue), it is interesting to see their reasoning for choosing sides in their situation. After the experience of war with a nearby civilization, the dyad appeared to want to avoid wars with civilizations close in proximity because their militaries can invade easily, and as with all wars, they can be costly. In the episode, the dyad was willing to alienate another civilization in order to appease a nearby civilization (thus avoiding going to war with the nearby civilization).

The episodes discussed highlight a trend of learning that occurred in the game, namely learning diplomacy and trade in *Civilization IV*. As can be seen, it might be difficult to isolate learning to a specific episode or series of episodes, as learning appears to progress throughout the whole series of game play. Each interaction shows a slightly greater complexity of understanding by the students. This is well supported by the game in keeping early interactions fairly simple, and steadily raising the difficulty of diplomatic exchanges. The other two granularities mentioned, *short episodes* and *sequences of episodes*, more closely follow idea of problematization, and will be noted and discussed while describing the other properties of learning episodes that follow.

4.2. *Levels of learning*

In most cases, students began first by focusing on learning the games' interfaces, and the functionality of basic interface controls. This allowed students to achieve basic gameplay. With this foundation, students had the foundation to move a level higher and begin looking at the games' strategies required to win. Success hinged on their proper understanding and interpretation of the interface and game features, as well as a logically understood goal set made achievable by the game. Learning was observed in overlapping, simultaneous levels in the games. These levels include:

- *Mastery of the basic physical interface*: usage of the computer such as the mouse, keyboard, display, etc. (outside the aims of this project)
- *Mastery of the software interface and functionality*: learning how to control the basic features of the game, such as learning the functionality of buttons, objects, and game features (illustrated in a subsequent example)
- *Mastery of advanced strategy*: this varied per game, but had a common thread of goal achievement and strategizing ways in which to win at the game (illustrated in the previous section)

Typically, learning the functionality of the interface takes precedence early in game play in order to achieve basic game control, which is followed by more advanced strategy to meet objectives. However, the learning of basic functionality of the interface occurred throughout all game play, as new features were often discovered later in the game.

4.2.1. *Mastery of the game interface: Controlling the camera view in RollerCoaster Tycoon 3*

The next example illustrates mastery of the game interface, as well as learning at the level of a sequence of episodes and peers as cues for learning. Game players are becoming frustrated with the camera controls. There is difficulty moving the game map over the area that they desired to work. The dyad is able to swivel the view around a fixed point, but that fixed point is not always the location they would like to focus their work. The problem manifests itself for a long time in game play, and eventually they figure out how to control the camera angle after asking the peer dyad. Figure 6 shows an example similar to what the dyad was looking at when trying to control the camera angle on their park.

The first episode highlights some of the trouble being experienced by the dyad in attempting to control their camera angle (view of the park):

L: I wouldn't. ↑Oh, no↓ (.5) °Gosh.° Confusing. ((*Changes camera view*)) ((*Camera is stuck in the mountain alongside the park*))
L: OK, °I'm getting kind of frustrated° ↓at this folks↓
R: Does it keep popping it back up?

Figure 6. Trouble controlling the camera angle/view of the park in *RollerCoaster Tycoon 3*.

L: ((*The camera view of the park keeps going from sky to ground*))
Yeah.
L: I can't get it, here, ((*Laughs*)) you do it, just try it.
R: ((*Takes over control of the mouse*))

Students become frustrated in their inability to move the camera. After no success, mouse control is traded between students (left hand to right hand student) and an explanation of understanding is offered. However, this is not enough to solve the problem. Later in the game, the problem manifests again:

((*A few minutes pass...*))
R: I can't get over there. I spent literally five minutes just trying to get over to the ride. ((*Zoomed camera in on park*))
L: Oh no. Wait why are we back to here?
R: ((*Swivels view of camera from left to right*))
R: ((*Laughs*)) I can't (.) Because when we left I guess the mouse moved.

Frustration has grown, as much time was spent focusing on moving the camera (unsuccessfully). Early in the episode, one student asked the researcher for help, who ignored the request. The episode occurred between passing periods where the

students had to show signed permission slips to their study hall teachers. Upon coming back to the game, the dyad hypothesized that the mouse had moved while they were gone, to explain why their view was centered on a remote area of the theme park.

Finally, the dyad consults the peer dyad to learn how to successfully control the camera angle:

L: Liz, do you know like how to move it so like you can like ((*Laughs*)) (.5) control it like perfectly so you know where exactly to go? Because we're like moving it and it's not even working. (.5) Like we're trying to get like down here and we're scrolling but it only goes to there. ((*Scrolls mouse to zoom in and out*)) ((*Clicked near the point where the camera is swiveling the view, off to the side of the park*))
Peer Dyad: Um you can scroll like by moving it to the edge of the screen. Move your mouse to like the edge of [the screen]
R: [Like this way] [That's what I] ((*Points to right side of screen all the way to edge*))
Peer Dyad: [Yeah just like that way]
L: ((*Points the cursor to the edge of the screen and the camera moves right, back over the middle of the park*)) OHHHHH.
R: ((*Laughs*))
L: ↑<u>What</u>.↑ No <u>way</u>.
Peer Dyad: It's easier that way.
L: Yeah it is. Geez. ((*Now able to view and look around park with camera successfully*))

In this case, a lingering interface problem inhibited the dyad's playing of the game, and was not resolved until the second period of playing. The dyad offered an explanation of their problem to a peer dyad. Resolution came after the peer dyad responded with advice on how to solve their problem. In this case, the dyad made use of a peer dyad as an informational resource in solving their interface control problem.

4.2.2. *Mastery of advanced strategy: The technology advisor in Civilization IV*

This example illustrates learning at the level of mastery of advanced strategy, as well as learning at the granularity of a sequence of episodes, and how game representations can provide cues for learning. In the following episodes from *Civilization IV,* the students make use of a feature showing the game's technological advancements that enables one to look ahead and see technological advancements yet to be unlocked. Each city in a civilization can contribute to researching technology and can produce items. Over several turns (number of turns varies per item researched)

Figure 7. Unlocking a technology item in *Civilization IV*.

teams will unlock technology items, which can be used to produce things for the civilization (workers, soldiers, etc.). Upon unlocking a technology item, the game offers a description of what was achieved and what it can be used for (Figure 7). This is followed by a list of choices of what to research next, as seen in Figure 8.

In Figure 8, choosing the first item labeled "Let's see the Big Picture" will pull up the "Technology Advisor", which shows a graphical tree of technologies that have already been researched as well as those that have not yet been researched, which can aid the choice of what to research next (shown below in Figure 9). The Technology Advisor in *Civilization IV* supports goal formation as well as motivation to unlock future technologies and use them in one's growing civilization:

((*Window pops up in game, explaining the new technology item the dyad unlocked*))
R: ((*Clicks first button called 'Let's see the big picture' which pulls up the 'Technology Advisor'*))[7]

[7]The "Technology Advisor" allows implications of decisions to be viewed by displaying a tree of technology items along with their contingencies. The "Technology Advisor" displays all 80 technologies available to the gamer (including those available later in the game) from left to right. The technologies on the left are less advanced then the ones further to the right.

Figure 8. Prompting to research a new technology in *Civilization IV*.

R: ((*Mouses over the different items to be researched next*))
L: ↑Iron working. Can remove jungle↑ ((Laughs))
R: ((*Scrolls through the 'Technology Advisor' from left to right according to advancement*))[7]
R: ''Build a Winery''? ((*Surprised*))[8]
L: °So much stuff.° 'Electricity'? ((*Scrolls through the 'Technology Advisor' at all the different technologies listed*))
R: ((*Clicks on 'Electricity'*))
R: ((*Scrolled to the end of the technology list*))
R: Let's go with uh = ((*Game gives them a list of technology items to work on next*))[9] °Pottery.° ((*'Pottery' chosen as next technological advancement*))[10]
L: You can get like into the (.) you can get advanced in this game.

[8] "'Build a Winery' provides access to the wine resource. It can be built only in a space with that resource." (*Civilization IV* Manual, p. 75)
[9] A technology will appear on your list only when you have learned the necessary prerequisite technologies.
[10] "Pottery allows your workers to construct cottages, which increase the commerce in their space. Pottery also allows you to build granaries in your cities." (*Civilization IV* Manual, p. 71)

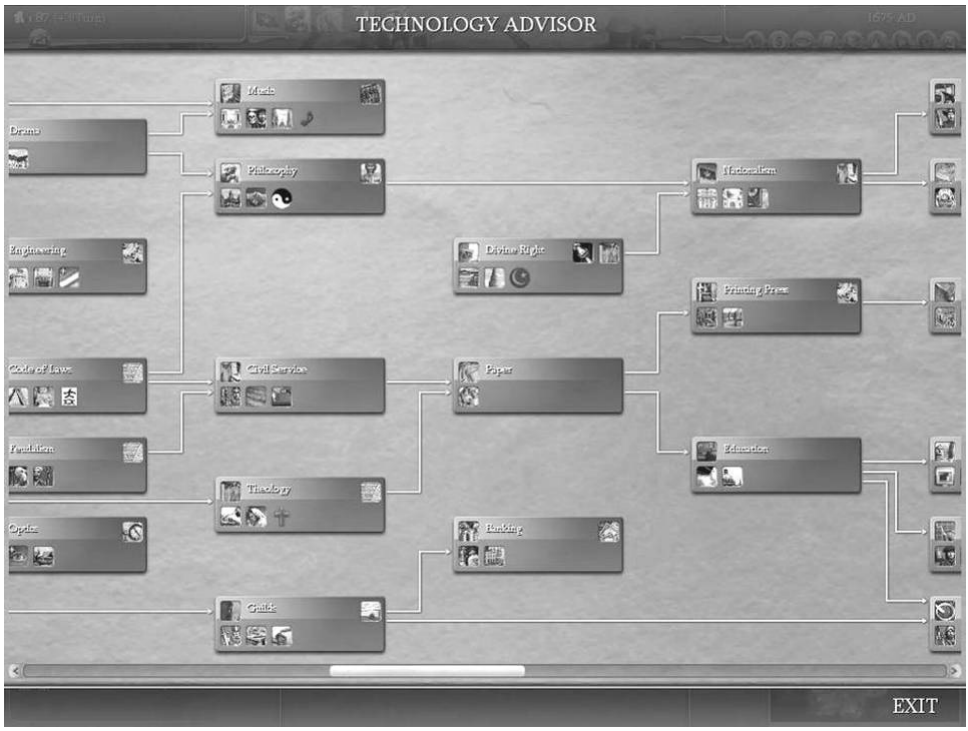

Figure 9. Technology advisor in *Civilization IV*.

In the prior transcript, the dyad unlocks a technology item, and pauses to see the implications of the new technology (what new products can now be built, what future technologies can be researched as a result). After growing curiosity of the hierarchy of technology items, the dyad decides to look at the "Technology Advisor" (see Figure 9). This visual representation manifests itself in goal formation, as the dyad mentions how "advanced" the game can become, appearing motivated to unlock and use future technologies.

Later in the game, the dyad revisits the "Technology Advisor" roadmap. Icons that have been unlocked are colored green, while those yet to be achieved are blue.

L: What should we (.) 'Code of Law'? ((*Scrolling through the list of technologies that can be researched next*))[11]
R: Hold on. Look for other kind (.5) click on 'Let's see the big picture' ((*'Let's see the big picture' pulls up the 'Technology Advisor'*))[7]
R: What do we need? ((*Looking at the 'Technology Advisor' screen*))
R: Like, what stuff do we have that we (.5) Mining leads to Masonry?

[11] "'Code of Law' enables caste system." (*Civilization IV*: Tech Tree & Specifications Charts)

L: ((*Mouses-over different technologies listed in the 'Technology Advisor'*)) I think the green ones are the ones we have. ((*Scrolls through 'Technology Advisor' screen from left to right*))[12]
L: We should probably get this. Says it leads to Monarchy. ((*Mouses over 'Monotheism'*))[13]
L: ((*Monotheism is not colored green*))
R: 'Monotheism'?
L: Yeah. Alright ((*Clicks 'Monotheism'*))

Technology is vital to one's strategy while playing *Civilization IV*. For instance, to develop more advanced military technology to win at warfare, one must unlock advancements in iron working, horses, etc. As these technologies are unlocked, they support the use of new materials and technologies in one's military. In this example, the game feature of the "Technology Advisor" visually displays goals in the game, and aids players in choosing and achieving those goals.

In the above sequence of episodes, the dyad makes use of the Technology Advisor in choosing their strategy. After game cues helped students discover the Technology Advisor in the first episode, the dyad followed by using it to select future technologies to research in the game. This also supported their evolving strategy in the game, which was partially developed with the aid of the Technology Advisor.

4.3. *Triggers for collaborative task pursuit*

During collaborative gameplay, the discovery of a problem and pursuit of related tasks was often caused by either some social or game cue. Social cues (such as overhearing peer dyads discussions) often led to the uptake of a related task in the game. Suthers (2006) describes task uptake as occurring when one takes "another's contribution and does something further with it" and may include student's "attentional orientation, information, or expressions of attitude, reified as media affordances allow" (p. 331). Additionally, cues in the video game might trigger the pursuit of a related task. The concerted pursuit of tasks in the game by student dyads, representative of collaborative learning and often set off by an environmental or interface cue, often lead to students pursuing a related task in the game.

Hidi & Renninger (2006) in their "Four-Phase model of Interest Development" discuss gaining interest and adding motivation to tasks in the first phase of interest development, "triggered situational interest". This might be set off by some sort of cue: either in the game, or socially. Analysis of the video data reveals several sources for information or cues that may lead to the pursuit of a task: they may come from specific game features (such as the game's representations and behaviors, as seen in the Technology Advisor example), or from social peers (while participating in

[12]Green boxes are unlocked items; blue boxes have not yet been researched yet.
[13]"'Monotheism' allows Judaism" and "enables organized religion". (*Civilization IV*: Tech Tree & Specifications Charts)

collaborative gameplay together, as seen in the problem solving of RollerCoaster Tycoon controls).

Social cues leading to pursuit of tasks are a feature of collaborative gameplay. Dyads tend to collaboratively negotiate their course of action, as well as share information with each other that they deem relevant. Game cues leading to the pursuit of tasks illustrate how particular game features can lead to the collaborative pursuit of a task in the game by the student dyads. Additionally, failure can often lead to the pursuit of tasks by triggering attention. Cues grab the attention of students and can trigger their subsequent pursuit of a related task. However, the pursuit of the task alone should not automatically be classified as learning, as focus is on the pursuit of a task (similar to the identification of a problem), without determining whether the pursued task is successful (showing some behavioral change or the resolution of a problem). While the majority of the found episodes exhibit a change in behavior and thus learning, it is possible that a game cue can trigger a missed opportunity (a task was chosen by the dyad for pursuit, and learning was not exhibited).

4.3.1. *Triggering learning: Failure at diplomacy in Making History: The Calm & The Storm*

In *Making History: The Calm & The Storm*, a sequence of episodes highlights game players' attempts to create successful diplomatic alliances and treaties. The dyad was rejected repeatedly; similar to what is seen in Figure 10.

Students repeatedly experienced failure at diplomacy. As shown in Figure 10, the message given as to why the diplomacy failed (the game feedback) was very limited and not very helpful in the generation of new strategies. However, students realized that diplomacy was an important aspect of the game, as will be shown in the following sequence of episodes.

The first episode of the sequence illustrates the students learning that they need to create treaties with other countries in order to succeed in the game:

L: It's ah, It's Germany. Didn't we declare war with them? ((*'War Expands' window pops up*))
Peer team: So who are you guys joined up with now?
L: Dude, we are all by [ourselves because we declared war] on everyone. ((*Clicked on 'Military' icon*))
R: [Yeah we're attacking everyone.]
Peer team: Awesome. ((*Laughs*))
L: Yeah let's see (.5) we're ((*Clicked on 'Diplomatic Agreements' icon*)) (.5) We have no alliances.
Peer team: Everyone hates you. Nice.
L: ((*Attempts peace treaty*))
((*Confirms the action taken*)) ↑OOOH.↑ Both of em. ((*'Peace offering*

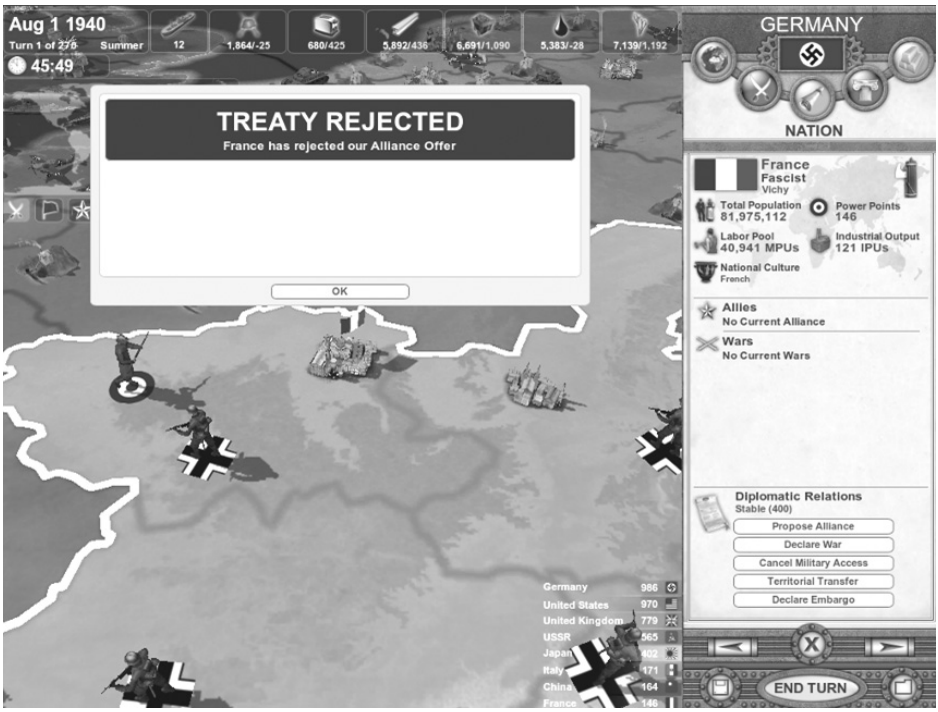

Figure 10. Diplomatic relations menu and a rejected treaty in *Making History: The Calm & The Storm*.

fails' window pops up))[14]
L: ((*Attempts another treaty*))
((*'Treaty Rejected' window popped up*))
((*Clicks 'Ok' to close window*)) Alright.

At the start of the next day, the pair makes it evident that they understand diplomacy as being important to their success:

L: No. We need to find out (.5) if we are at war with anyone.
((*Clicked on 'Diplomatic' icon*))
No current wars. ((*Scrolled across map*))
Let's get some alliances before we start any wars with anyone. (2.0)
Should be alliances with people around us or with people from far away and then take over all these?
R: We should make alliances with bigger countries. Like USA and stuff, Russia.
L: Alright.

[14] "If you want to demand peace or offer surrender, you must first seek alliance approval." (Making History Manual, p. 26)

Following, the dyad makes several attempts to make alliances with other countries before beginning any military campaigns. After three failed attempts at diplomatic action, the group shifts focus:

L: Alright, we're gonna have to start some wars now.
R: Definitely. It's the only way to uh, (.5) to win this game.
L: ((*Scrolls over to Europe*))
((*Zooms in on Europe*))
Then - ((*Clicked on 'Military' icon*))
R: Stay, stay on this for a second. (.5) Is there like a (.5) what the hell?°
L: ((*Opens up instruction manual to game*))
R: ((*Picks up Game Interface brief booklet*))

Learning from their experiences on the first day, the dyad realized the need for alliances with other countries. However, they were unable to create any successful alliances. Repeated failure at diplomacy leads the dyad to begin fighting wars, even though they realize success will be very difficult without alliances. This leads to the purpose of the game breaking down a bit, which can be seen as the dyad begins to declare war on random countries:

R: ((*Has control of mouse*))
((*Clicks on Spain*))
((*A warning screen pops up*))
((*Clicks 'ok'*))
((*Chuckles*))
((*War is declared by Spain*))
L: What?
R: ((*Clicks 'OK'*)) It's just Spain. Spain sucks.
((*Mouse controls traded from R to L*))

Later in the game, a successful alliance is made with Italy. The dyad is surprised, based on their lack of success in previous diplomatic efforts. However, little reasoning is given as to why the treaty was successful:

R: Try to make friends with Italy. (.5) More to the right. In the green there on the bottom.
L: Here? ((*Scrolls around Europe*))
R: Yeah.
L: ((*Clicks on Italy, then follows sequence to make a treaty with them*))
L: ((*Clicked on 'Diplomatic' icon*))
((*'Our Alliance Forms' popped up*))
R: ↑YEAH. ((*Laughs*)) Yes. Nice. Alright. ((*Scrolls across continent*))
R: Can we use their troops?

L: °Let's try this.° No they'll just back us up now.
R: Good we need some back up.

Further alliances were attempted after the alliance with Italy, however all were unsuccessful. Most of the gameplay following focused on military conquest. The dyad spent most of their time moving military forces around the map attempting to gain territories. Often the dyad lost wars after spreading themselves too thin on too many different battlefronts.

In comparison to students playing *RollerCoaster Tycoon 3* who had difficulty controlling the camera view, students struggling with diplomacy in *Making History: The Calm & The Storm* were frustrated from the lack of feedback from the game. Moving the camera angle in *RollerCoaster Tycoon 3* highlights a problem on the level of controlling the interface, while problems with diplomacy in *Making History: The Calm & The Storm* appeared to be at the strategy level. Accordingly, players of *Making History: The Calm & The Storm* adjusted their strategy by giving up on diplomacy and moving on to other tasks (warfare).

Student's lack of diplomatic success in *Making History: The Calm & The Storm* severely inhibited the nature of the game play, which was typified by lost military campaigns. While the game successfully tied the relationship of military operations to diplomacy, the lack of successful diplomacy and meaningful feedback created situations where winning at the game was very difficult. While failure can often motivate and lead to learning, repeated failure in the game might lead to the redirection of game players' attention to other game areas.

In this case, even though the game communicated to game players that diplomacy was important for their success, students gave up after experiencing repeated rejection of treaties and alliances (with little feedback as to *why* they failed). This may be a missed opportunity: while some failure may help bring attention to a feature of a game, repeated failure, especially at the strategy level of play, eventually detracts attention from the particular game feature by lowering the sense of accomplishment (as the task seems unachievable, and other tasks are chosen). A similar problem occurred in *RollerCoaster Tycoon 3* in the linking of ride entrances and exits to a footpath, which seemed to negatively affect gameplay.

4.3.2. *Redirection to neglected game aspects in Making History: The Calm & The Storm*

Besides failure, specific game features can serve to redirect attention to other aspects of the game. The previously mentioned example from *Civilization IV*'s avatar interactions (prompts for trade proposals, peace, etc.) caused learning to occur by focusing attention on another area of the game, which could have been easily forgotten or neglected. Game redirection can draw game players towards new features of the game that have not yet been used, allowing game players to make use of those features. An example follows from *Making History: The Calm & The Storm*, where

the pair receives notification of another country (Canada) taking control of one of their states (Michigan):

((*'National Events' popped up telling the pair that Canada seized control of Michigan*))[15]
L: What Canada seized control of Michigan?
R: Oh crap.
L: What? ((*Clicks on 'Mini Map'*))
L: Where's Michigan? ((*Scrolls over continent to find Michigan*))
R: Oh shoot there it is.
L: Not occupied, Oooh who did?
R: We can take that back. Canada. We can't take ↓that from Canada.↑
L: Dude, ah. ((*Zooms in on map*))
R: Do we have like any armies ↓over there?↓ ((*Clicks through the different map views*))
L: I don't know where the °hell (.5) our armies are.°
...
R: We are going to kill them. ↓How do you move those planes?↓
L: ((*Clicked on an airplane in Georgia*))
((*'Air Force' menu popped up*))
((*Clicked on 'Rebase' in the 'Air Force' menu*)) Oh here we go. (.5) Canada.
R: Yeah go to Minnesota. Then we can attack them from there.
L: ((*Clicks on Minnesota*)) Go. ((*Scrolls over continent*))

As can be seen above, the pair becomes fired up when Canada takes a state away from them. The game notified the dyad (a message was displayed) by saying that Canada had seized control of Michigan. This resulted in a redirection of attention to Michigan, and lead to strategizing of how to get it back. Incidentally, this also led the pair to discover how to make use of their airplanes to attack Canadian forces.

Throughout game play, game cues triggered new strategy development and gave game players feedback. This often served to add motivation and shift attentional focus to another aspect of the game. Cues could come from a game's ability to detect an unused feature, a game message or pop-up, or from watching the behavior of game objects. Failures often served to draw attention and motivate pairs to work on tasks related to the failure. However, failures could hinder interest and task pursuit when negative conditions exist, such as the lack of feedback or the experience of frequent, repetitive failure. These feedback mechanisms triggered learning by prompting pairs to take up new tasks. The design of game cues are important, as they should help trigger the pursuit of related tasks that encourage learning activities.

[15] "Here you can learn about production, idle cities, resource shortages, trade changes, completed research, and industrial upgrades." (Making History Manual, p. 11)

5. Discussion

5.1. *Summary of findings*

Learning was observed at different granularities, occurring either as a *short episode*, a *sequence of short episodes*, or a *trend* spread over time. Trends were often observed in a moderately used game feature whose complexity and use increased over time. Short episodes and sequences of episodes often followed problematization, where pairs discovered a problem and pursued a task, followed by the problem's later resolution (when the task was successfully completed). Cases where tasks were not completed successfully or appeared to be inhibited by action that did not move pairs towards their goals were marked as missed opportunities for learning and reserved for later analysis.

Learning appeared at several levels: learning the *physical interface* (the high school students in the study have already mastered using a computer and its physical interface), learning to use the *game interface* (the basic usage of the game interface, including icons, objects, etc, and their corresponding functionality), and learning *advanced strategies* required to win the game (behavior in line with achieving goals set forth by both the game itself and game players, aimed at achieving something in the game such as winning or fulfilling other gratifications).

Although all three levels appeared simultaneously through gameplay, there was a progression through the levels of learning with more emphasis on the lower levels early in gameplay. Advanced strategies were typically on a larger scale, and examined what was being accomplished as a whole during game play (such as motivations to play).

Finally, *learning often appeared to be triggered by social peers or by particular game features*. These factors added motivation and shifted attentional focus to another aspect of the game, which often lead to instances of learning. Failures often served to draw the attention of the students and motivated them to work on tasks related to that failure, suggesting that failure can be used as a tool in games to promote learning. However, there were examples where failures hindered interest and task pursuit when negative conditions existed, such as the lack of feedback from the game or the experience of repetitive failure. Failure can either positively or negatively impact learning, depending on the nature of the failure being experienced by students.

5.2. *Comparison of findings with post-game interviews*

During post-game interviews, students reported that the games were fun and interesting; however, certain parts of the game were difficult to learn or use. Specifically, students listed game "controls" as being somewhat difficult, and suggested that a teacher could help make the learning more efficient and effective by demonstrating proper use. Most student comments corresponded to the level of learning previously described in the analysis that focused how to use the game interface and its

corresponding functionality. Students did not express difficulty in the other two levels of using the computer interface or developing advanced game strategies.

Teacher presence was limited in the study, occurring only occasionally during *Making History: The Calm & The Storm*. This was to be expected, as teachers were not familiar with the games being used and did not have time to learn the games or integrate them with their curriculum. In *Making History: The Calm & The Storm*, the teacher was not well familiarized with the game, but offered general tips that correlated with the time period (World War II) and some general warfare strategies. Students responded positively in the interviews that this advice was helpful in generating their game strategies. This may be due to the presence of the teacher in the room during the interview (the teacher was present because he moved his study hall to the computer lab in order to assist in the study); however, students were not prompted concerning whether additional teacher presence would be useful: all information was volunteered. Students who played the other two games (without a teacher's presence during interviews) mentioned this as well. Further implications of teacher role and curriculum integration could be investigated in future work.

In general, students reported that they had fun, enjoyed the game, and thought it was relatively accurate (to history, or to business, depending on the game). Other comments during interviews included the appreciation of the complexity of *Civilization IV*, confusion and boredom in *Making History: The Calm & The Storm*, and all playing *RollerCoaster Tycoon 3* said it was fun but learning some of the controls was difficult. Regarding collaborative game play, most of the students said they preferred controlling the game interface (being in charge of the mouse and keyboard input devices); however, students mentioned that they still enjoyed playing collaboratively because the collaboration encouraged peer discussion and helped ease the learning of the game interface and its associated functionality.

One of the most interesting aspects of the interview was when students were asked "what they feel they accomplished" by playing the game. This question was often very difficult for students to answer, and responses showed rather brief and shallow replies. However, analysis of video data revealed that a considerable amount was learned by students, and was supported by the nonverbal behavior of students during the interviews that showed that students were struggling to put their experience of playing the game into words. This indicates a large amount of tacit knowledge was acquired by students, which is supportive of claims by Gee (2003) about the way in which learning occurs in games.

5.3. *Implications for the design of game interfaces*

Regarding the granularity of learning episodes, game designers might examine typical use of game features and game players' ability to master those features. Aspects of the game should be properly matched to their intended use. For instance, most interface controls should be designed such that game players can properly infer meaning quickly, rather than in a sequence of contingent episodes (where it may

have taken several tries to learn the interface item). Sequences of learning episodes for simple interface controls (that might have been accomplished in a short episode) may shed light on interfaces that are in need of improvement.

Likewise, overall game activities (purposes and objectives of playing the game) might be designed to follow the *trends* granularity, so that a slowly growing complexity can evolve through the game. These most likely will fall into the advanced strategy level of learning, but will also inherently involve the lower levels of learning as well (learning the game interface, as well as the physical computer interface in order to accomplish goals in the game).

The analysis of game play of this study could also reveal problems in game design, such as non-obvious controls (such as the difficulty encountered by students in controlling the camera angle in *RollerCoaster Tycoon 3*), or other adverse effects in strategy (such as students in *Making History: The Calm & The Storm* failing to create diplomacy in the game, and redirecting their efforts towards making war). Both of these examples might have been avoided with additional game feedback. Some simple adaptability might be programmed into games to detect common problems, and respond with additional information or feedback to give students clues in learning the corresponding game feature.

Additional feedback might be given through well designed game representations that support the kind of game activity and learning they intend. Differences between feedback on diplomatic actions in *Making History: The Calm & The Storm* (a message displaying a failed attempt) and *Civilization IV* (an animated character showing emotion, thus utilizing nonverbal communication channels) yield different kinds of learner behavior, in large part to the design of the representations.

Results also demonstrated the ability of game cues to draw the attention of students to other portions of games. Failure is a specific kind of game cue that when used properly, can motivate students to accomplish a task. As seen in the final example from *Making History: The Calm & The Storm*, students were motivated to win when a nearby nation took control of some of their territory. Students responded with a corresponding discussion of strategy and course of action to correct the situation. However, frequent failure can detract game players from making use of a game feature. Game designers should create appropriate difficulty structures in games to avoid recurring failure, and provide appropriate feedback when necessary in order that game players have information in which to compensate and adjust their strategies to achieve success.

5.4. *Future work*

This study examined learning using the gaming medium, and explains how that learning was accomplished. Although games as a whole are not a perfect treatment for learning, they can provide a different 'kind' of learning in comparison to other traditional, formal learning activities. Every video game is unique, and must be considered on its own merit.

Ongoing analysis is focusing on the collaborative appropriation of game resources and peers in game play that lead to successful instances of learning. Additionally, an analysis of episodes demonstrating a missed opportunity for learning will reveal potentials for improvement of the games. Learning episodes already identified are being revisited to identify how game affordances influenced and were appropriated in those learning events. Convergence will also be examined: whether dyads appear to be grounded (on the same page; making a concerted effort), or whether they appear to be on their own train of thought. Initial findings show student game players having preferences for particular kinds of game representations, as particular representations were more readily interpreted. Game representations affected group behaviors through their display of information and the way past activity and future potentials were displayed. Additionally, students displayed an evolving set of social norms in their interactions with their teammates and in their interactions with other dyads, and these, in turn, affected student game play and learning.

Future work focusing on the role of the teacher is needed. Limited teacher interaction was recorded by this study, and students indicated in the interviews that teachers could improve the learning process, especially in understanding the use of the game interface. Teachers demonstrated their help in offering strategy guidance to students as well. Alternatively, findings suggested that students could benefit from occasional failure. The role of the teacher and the appropriate amount of assistance needs further investigation.

Additional work is needed to examine how games meet educational standards. While outside of the focus of this study, future work needs to show convergence of learning outcomes with games and existing teaching standards. Without this information, games will face an uphill battle working their way into classrooms. Initial benefits of games for learning have been explored, but further work on their integration with existing teaching standards and curricula is needed.

6. Conclusion

Results of this study showed the usefulness of a broad conceptualization of learning. Learning was shown to occur across several granularities and levels. Future work is needed to further investigate the use of affordances, roles that games play as part of an integrated curriculum, and how exactly teachers can play a role in the learning that takes place. Considerable effort lies ahead in integrating games with existing educational practices. However, the opportunities for learning afforded by games demonstrate the need for continuing this effort in order to ensure that the benefits offered by games are harnessed in contemporary classrooms.

A wealth of existing literature suggests that kids today are undergoing a radical change in the way that they learn, preferring the active problem solving and immersive environments provided by games they play outside of school. Educators need to be prepared for this transformation and be ready to embrace new teaching methods that fully engage current and future generations of students. Traditional

instruction is slowly losing potential to fully engage students on a level of which they are capable. Continued research into specific game designs will further push the envelope in games' ability to create learning opportunities and teach in new ways that were previously not possible. Games have the ability to help transform learning for kids, changing learning from something thought of as a chore to something enjoyable. In order to be prepared, an understanding of the process of how learning actually occurs is required by educators and game designers. This is the sort of work initiated by this study. Additionally, the understanding of this new learning process is required in order to continue developing new games that better support that process.

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[16]The following three video games were purchased by the researcher for use in this study:

Roller Coaster Tycoon 3 (http://www.atari.com/rollercoastertycoon)

Making History: The Calm & The Storm (http://www.making-history.com/edu)

Sid Meier's Civilization IV (2K Games) (http://www.2kgames.com/civ4)

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