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THE ICCE FRAMEWORK: FRAMING LEARNING EXPERIENCES AFFORDED BY GAMES

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ABSTRACT

There is a need for game-based learning frameworks that provide a lens for understanding learning experiences afforded in digital games. These frameworks should aim to facilitate game analyses, identification of learning opportunities, and support for learner experiences. This article uses the inquiry, communication, construction, and expression (ICCE) framework to examine a mathematics game (Dimension M) to support learners. The study was conducted using mixed-methods with interviews, observations, and pre-post assessments, in addition to analyzing learner experiences using the ICCE framework. Results showed that the twenty 9th-graders in the game-based learning course had statistically significant mathematics gains, but not for motivation. Interpretive results highlighted how ICCE as enacted in the game design supported learners' experiences. The ICCE framework may be a valuable tool for aiding teachers to assess the efficacy of games for learning and for students to benefit from the possible designed experiences within games.

INTRODUCTION

Digital game-based learning has been largely accepted as one way to facilitate student academic achievement and motivation in both formal and informal settings (Young, Slota, Cutter, Jalette, Mullin, Lai, et al., 2012). However, researchers have argued for a more nuanced approach to game-based learning in order to

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improve learning experiences and the efficacy of games for supporting students (Tobias & Fletcher, 2012). Specifically, there is a paucity of empirical studies that are aimed at developing holistic frameworks for assessing games as educational technologies to support learning (Killi, 2005; Rice, 2007). The assessment of technologies as learning technologies is essential for supporting claims about how well they perform as educational innovations (Ferdig, 2006).

Gredler (1996) argued that games and simulation needed stronger research paradigms and that research since the 1950s has been without common frameworks. More recently, scholars have argued for frameworks in games and learning to support researchers, teachers, and learners not only in employing games, but to also aid in the process of elucidating the relationship between specific game mechanics and learning outcomes such that substantive conclusions can be made about the effects of game-based learning (Steinkuehler & Squire, 2014). In this article, we build on the works of Dewey (1902) and Bruce and Levin (1997) and extend inquiry, communication, construction, and expression (ICCE) as a framework for examining learning experiences afforded by games to support student learning and affect.

We begin with a brief review of existing frameworks for evaluating games followed by an operationalization of the ICCE framework and our stance on learning. Next, we describe the research question and methodology. The results section reports the outcomes for student learning and the analysis of Dimension M, a mathematics game that was played by freshmen urban high school students as part of a game-based learning elective course. The concluding sections discuss the relevance of ICCE for supporting student learning and motivation using games, and the implications for including ICCE in designing games for education, teaching with games, and researching game-based learning.

EXISTING FRAMEWORKS FOR EVALUATING GAMES

There are few research frameworks that focus on aiding game selection and use, analyzing the game as a holistic system, and studying learner experiences in games. For instance, Mitgutsch and Alvarado (2012) developed the Serious Game Design Assessment Framework, which focuses on examining the consistency between the objective of a game and essential game design elements such as content, fiction (characters) and narrative (plot), mechanics (learning curve, rules), aesthetics (setting) and graphics (visualization), and the framing (target group, topic). Similarly, Rice (2007) created a tool for teachers to evaluate the inclination of video games towards encouraging higher order thinking in learners. This tool included components such as requiring users to assume a role, offering interaction through avatars and with non-player characters (NPCs), presenting puzzles that require effort to derive solutions, and immersing players in systems that replicate real-life (Rice, 2007). Finally, Killi (2005) designed the experiential gaming model to assist design and analysis of educational computer games for facilitating a flow experience. The model emphasizes the importance of providing the player with meaningful feedback, clear goals, and challenges that adapt to his/her skill level, opportunities for creative solution generation, and reflection as factors contributing towards sustaining players' engagement and as a means to maximize the impact of educational games.

The described frameworks are essential in that they target different audiences (teachers–Rice, 2007; learners–Killi, 2005; designers–Mitgutsch & Alvarado, 2012) and focus on different teaching and learning dimensions (cognition–Rice, 2007; motivation–Killi, 2005) in the process of evaluating the merit of a game. We introduce the inquiry, communication, construction, and expression (ICCE) framework that synthesizes the strengths of the frameworks discussed above in acting as a lens for analyzing learning opportunities in games and facilitating learners' knowledge construction and motivation to learn.

ICCE is nested in a larger framework known as the Game Network Analysis (GaNA; see Figure 1), which was conceptualized for facilitating teachers and researchers in introducing game-based learning in classrooms (Foster, 2012).

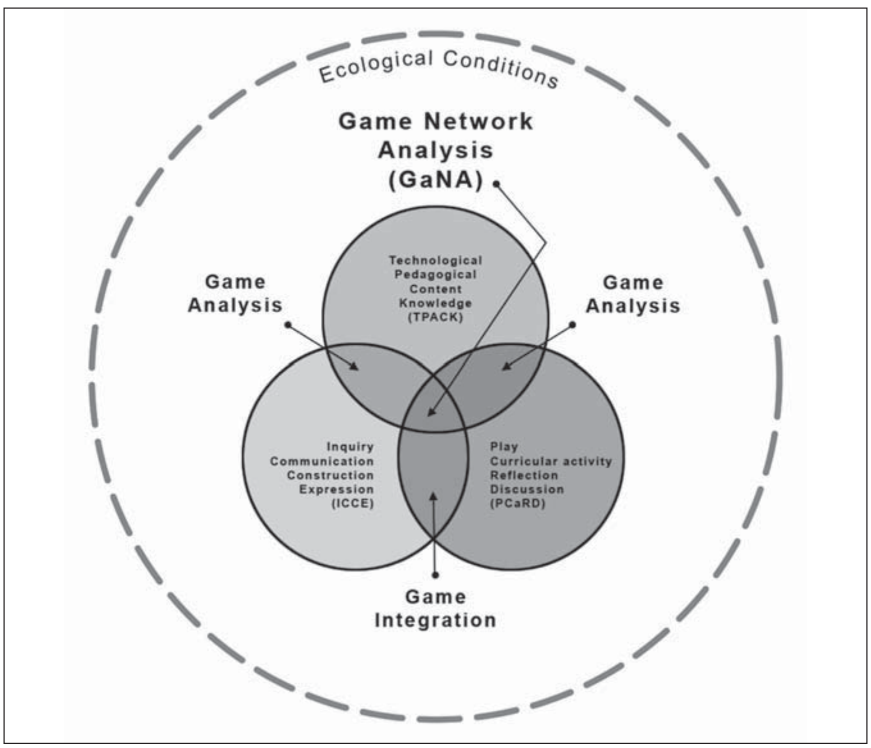

Figure 1. The Game Network Analysis Framework.

GaNA provides a method for game analysis and game integration within an existing or a new curriculum (Foster, 2012). GaNA provides an adaptive structure that teachers need within their classroom context to focus on the pedagogy and content of games and then employ games for supporting teaching and learning. Therefore, GaNA includes: (a) game analysis for technology, pedagogy, and content using the Technological Pedagogical and Content Knowledge (TPACK) framework as a lens (Foster, 2012; Foster, Mishra, & Koehler, 2011); and (b) the Play Curricular activity Reflection Discussion (PCaRD) model which includes ICCE for integrating games in classrooms in a step-by-step approach to support teachers (Foster, 2012). Thus, the ICCE framework bridges game analysis and game integration by aiding teachers in the identification of learning experiences and the design of opportunities that may be lacking in a game.

GaNA has been used to design informal learning environments for science and art (Foster & Katz-Buonincontro, 2014; Zhu, Foster, & Muschio, 2013). It has also been used in formal settings such as classrooms with teachers in urban and suburban schools to nurture learning experiences and supporting student learning in game-based learning courses in mathematics, science, social studies, and systems thinking for upper elementary, middle, and high school students (Shah & Foster, 2014b).

In this article, *we report on the role ICCE played as a method to identify learning experiences in games and briefly highlight the design of ICCE opportunities using PCaRD* (see Figure 2).

THE INQUIRY COMMUNICATION CONSTRUCTION AND EXPRESSION (ICCE) FRAMEWORK

Dewey (1902) argued that school curriculum should be sensitive to students' interests, personal background, and prior experiences since it facilitates educators in gaining a deeper understanding of students' learning. Dewey (1956) argued that it was essential to capitalize upon learners' natural curiosities; that is, "the interest in conversation, communication; in inquiry, or finding out things; in making things, or construction; and in artistic expression" (pp. 47-48). Building on the work of Dewey's conception of learning, Bruce (1998) highlighted the following considerations for using new technologies in education: (a) the nature of affordance provided to the learner for advancing their experience; (b) an aid for learners to construct meaning from their experiences; and (c) the relation among content, media, experience, tasks, and knowledge construction. Bruce and Levin (1997) proposed a taxonomy for the utilization of technology as media for inquiry, media for construction, media for communication, and media for expression. We *depart and extend* on the notion of ICCE as used by Dewey (1956) and Bruce and Levin (1997) and argue that a single technology, in this case every comprehensive digital game for learning should provide opportunities for ICCE to catalyze deeper educational experiences in a Deweyan sense (Shah & Foster, 2014a). Deeper

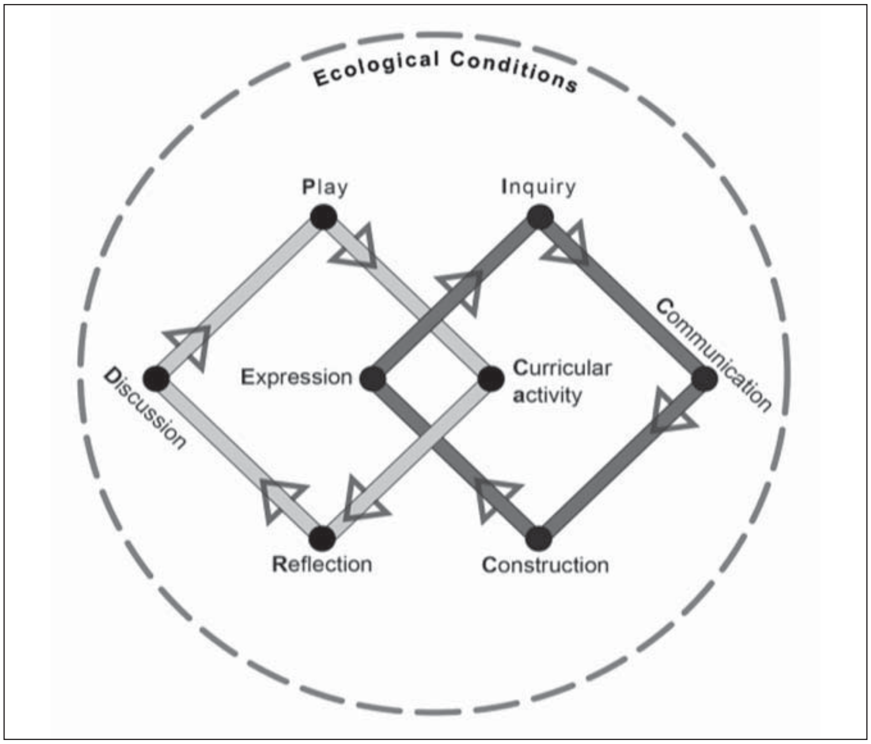

Figure 2. The relationship between ICCE and PCaRD for learning.

educational experiences involve processing both within individual minds and through social interaction in a community (e.g., mathematics teaching in a classroom) to aid learners' interpersonal and intrapersonal skills (National Research Council, 2012).

Below we describe what constitute ICCE experiences, but before doing so a brief overview of our views on learning and student motivation within this context is offered. Each component within ICCE is described separately in order: (a) to obtain a clear sense of their contribution to knowledge construction and motivational valuing of learners in games; and (b) to understand how games may vary in the amount and nature of ICCE experiences based on the expected learning goals.

STUDENT LEARNING AND MOTIVATION

Digital games provide contexts for learning as conceptualized by the situative perspective (Greeno, Collins, & Resnick, 1996). Knowledge refers to an activity (as opposed to an object), is always embodied (as opposed to abstract), is reciprocally constructed as part of the individual- environment interaction (as opposed to either objective or subjective), and involves whole persons (as opposed to disembodied minds; Barab, Bransford, Greeno, & Gee, 2010). Research has demonstrated that learning takes place through gaming. For instance, Barab, Heiselt, Hickey, Zuiker, and Sadler (2010) showed that 4th graders learning in Quest Atlantis were able to learn science content at a significant level. However, if game-based learning is to make a significant difference in informing the research on learning, a perspective on learning is needed that goes beyond content knowledge to a more generative or synthesized understanding of content knowledge and student motivation, particularly student valuing as intrinsic interest and self-regulation. Researchers argue that digital games support students in developing interest (Foster, 2011; Shaffer, Squire, Halverson, & Gee, 2005). One way this occurs is by using games to provide situational interest that may lead to personal interest through sustained gameplay (Schraw, Flowerday, Lehman, 2001). In addition, as learners engage in gameplay, the in-game scaffolds may provide co-regulation (McCaslin, 2009). Sustained co-regulation facilitates the development of learners' self-regulation (Hadwin & Oshige, 2011). Thus, it is expected that as learners play well-designed games they should develop personal interest or intrinsic interest and by extension content knowledge. Additionally, learners should become more self-regulated because of the scaffolds and opportunities for ICCE in the environment (class and game).

Thus, learning is conceptualized in this article as a situated process between the student, the game, and the classroom environments. Affordances for ICCE through game play and teaching situations involving curricular activities, reflection, and discussion support generative learning and engagement (see Figure 2).

OPERATIONALIZING ICCE EXPERIENCES

Inquiry is an iterative process that originates from the questions players[1] generate, or the problems they identify from their explorations in the game environment (Bruce & Casey, 2012). Dewey (1956) argued that people naturally like to inquire. This leads players to act in multifaceted situations by developing and testing solutions until a satisfactory change over the situation is attained (Talisse, 2002). Specifically, players' curiosities lead them to carry out investigations (e.g., making observations, gathering information, constructing explanations; National Research Council, 2012). This is followed by a period of making associations in which players must continue to act to adjust to unexpected changes they encounter within the environments and reason the direction in which they wish to steer their investigations (Chin & Chia, 2004). While inquiry is largely guided by personal

[1] The designations players and learners and the actions playing and learning are used interchangeably.

experiences, social interactions also shape its direction. As such, players extend the scope of their inquiries by discussing their experiences and conclusions with peers (Bruce & Casey, 2012). Upon reflection, players gain new insights, allowing them to decide between bringing a closure to their existing inquiry and pursuing new questions (Bruce & Casey, 2012). Additionally, successful inquiry is influenced by several affordances within well-designed games: (a) the objective(s) of a game is tied to the actions of the player (Beatham, 2008), (b) game players are usually assisted through guided discovery-based learning (Mayer, 2004), and (c) the process of inquiry results in mastery learning orientation (Foster, 2011).

Communication in games encompasses player-game and player-peer interactions. This sometimes involves "talk back" to players' actions through just-in-time and on-demand feedback (Gee, 2009). The communication generated from the player-game interaction adapts to learners' zone of proximal development through the introduction of problems and activities that advances in complexity to support learners' growing competence (Vygotsky, 1978). When the communication is useful, contextual, and situated in the world enacted within the game, and when learners can interpret the outcomes of their actions in real-time and posthumously, it guides players' progress towards fulfilling game objectives and making purposeful learning gains socially and academically (Flynn, 2009; Gee, 2005). Effective communication in games can be compared to the role of a facilitator, which offers timely modeling, coaching, scaffolding, and fading to players (Collins, Brown, & Newman, 1989). In this way, learners can begin to identify with the culture of a given community of practice (Foster, 2008; Markus & Nurius, 1986; Shaffer, 2004).

Construction of useful knowledge (Whitehead, 1929) occurs when games aid learners in demonstrating their understanding of phenomena through the design and creation of artifacts (Chin & Chia, 2004). For construction, players must have the opportunity to create or build artifacts that represent their knowledge. This provides players with ways of moving beyond internal knowledge construction. A sole focus on incremental knowledge gain or performance is insufficient for internalizing what is learned. Learners need many opportunities for knowledge construction, re-construction, and de-construction (Goldman-Segall, 1998). As such, this requires that games facilitate players in constructing both interdisciplinary and disciplinary knowledge by: (a) engaging learners' prior knowledge (e.g., academic, cultural, and social) and preconceptions with big ideas; (b) integrating higher-order thinking skills in the context of subject-matter knowledge; (c) letting players relate what they learn with their personal experiences and vice versa; (d) revealing the implications of their choices in the game; and (e) aiding learners in understanding what it means to *do* in a particular disciplinary or interdisciplinary area (Donovan & Bransford, 2005).

Game worlds serve as a legitimate media of expression and self-representation (Steinkuehler, 2010) through opportunities for sharing ones emotions, feelings, values, and ideas (Bruce, 1999). The relationship that develops between players' projections of their personal goals, the values they adopt from virtual characters, and the demands of the games' narrative influences players' learning experiences (Gee, 2008) and identity (Katz-Buonincontro & Foster, 2012). It is imperative that games encourage free expression; however, learners benefit when the game is critical of ideas and choices expressed (Donovan & Bransford, 2005). When expression is an integral part of learning in games, the environment resembles a participatory culture (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2009).

Within our theoretical lens, the ICCE framework defines the educational value of games from a Deweyan stance (Shah & Foster, 2014a) as well as learning couched within students experiences and connections to trans-disciplinary knowledge that are mediated by technology (Kereluik & Mishra, 2012), and skills such as foundational-knowledge (e.g., content knowledge), meta-knowledge (e.g., critical thinking), and humanistic-knowledge (e.g., ethical awareness; Mishra & Kereluik, 2011). Additionally, the ICCE framework allows ascertaining how games support learners' motivational valuing of an academic domain through the development of personal interest, identity formation, and self-regulation (Foster, 2008). In this article, we explore opportunities that the commercial educational massively multiplayer online game (MMOG)–Dimension M afforded that are grounded in inquiry, communication, construction, and expression, and how this influenced student learning and motivation. We also briefly describe the ICCE opportunities that were designed through the Play Curricular activity Reflection Discussion (PCaRD) model in order to overcome the limitations of the game and to meet students' learning and motivational needs with learning mathematics in a game-based classroom.

RATIONALE FOR SELECTING DIMENSION M

Dimension M is a commercially popular educational MMO first- and third-person server-based game designed to engage students in mathematics practice. Dimension M is comprised of four mini-games: Tower Storm, Velocity, Meltdown, and Swarm. In these mini-games, players locate and collect colored balls spread across the undulating game environment, enter into a tunnel and run through an energy beam to answer multiple-choice questions. Each of the mini-game has ways for players to earn bonus points and power-ups. For example, the more the number of spheres players collect, the more points they can earn for every correct answer.

Researchers have used Dimension M and reported mixed results in achievement and motivational gains (Kebritchi, Hirumi, & Bai, 2010; Ritzhaupt, Higgins, & Allred, 2009). In their experimental study conducted with 193 high school students in classrooms and school labs, Kebritchi and colleagues (2010) found statistically significant differences for mathematics achievement, but not for motivation. In a quasi-experimental study, Ritzhaupt and colleagues (2009) noted a statistically significant increase in students' attitudes towards mathematics self-efficacy for 255 middle school students. There was no statistically significant change for mathematics achievement.

Kebritchi and colleagues (2010) recommended further investigation to better identify the cause of the effect of Dimension M on achievement and motivation. Ritzhaupt and colleagues (2009) recommended researchers to go beyond documenting game effects. They urged researchers to consider explaining the effects, by focusing on game design and the methods that were used to integrate the game. We addressed these issues using the Play Curricular activity Reflection Discussion (PCaRD) pedagogical model for game-based learning. In this article, we focus on the design of Dimension M by analyzing the affordances and constraints of the game to provide inquiry, communication, construction, and expression (ICCE) experiences. We applied the ICCE framework to examine Dimension M and explain the result of the effect of the game on students' knowledge construction and motivation to learn mathematics. Thus, we investigate the following research question, "*How does Dimension M support opportunities of ICCE and impact student learning and motivation to learn mathematics?*"

METHODS

We used a concurrent mixed-methods research approach (Creswell & Clark, 2007; Tashakkori & Teddie, 2003) to examine Dimension M to identify the learning experiences the game afforded that are grounded in inquiry, communication, construction, and expression (ICCE), and to understand student learning through their engagement in the game. A mixed-method approach was used as researchers quantitatively assessed mathematics knowledge gain using the game and explored interpretively the process of learning.

Participants and Setting

Dimension M was implemented as part of a year-long research project in a 9th-grade elective course using game-based learning. The study was conducted in an urban high school situated in a large U.S. Mid-Atlantic city. Dimension M was used for one term from September to December with the Play Curricular activity Reflection Discussion (PCaRD) model to empower teachers and support student learning in Mathematics.

As a classroom-based study, all 23 students who were a part of the course were included in the study. However, only 20 students (11 females, 9 males) completed all study activities involving Dimension M. Parents enrolled their children in the course after researchers, teachers, and administrators described the potential of the course; thus, participants were selected conveniently. However, these students were atypical game players averaging less than 4-hours of gameplay as compared to the U.S. national average of 7 hours each week for children between 8-18 years old (Rideout, Foehr, & Roberts, 2010). Ninety percent of the students identified as

African American, with the remaining being Latino, Latina, and White. Overall, the school had 97.9% African-American enrollment. In addition to the students, one male teacher (one mathematics/technology teacher) with 3 years of teaching experience in K-12 participated in the study.

The course was offered once a week for a period of 100 minutes that was separated by a lunch break. All class activities occurred in a computer lab with 30 desktop computers. Data from participants who did not complete the assessments or participants with missing data were excluded from the analysis.

Data Collection

Qualitative data sources included interviews with seven students. Students were chosen conveniently to represent a range of interest in the subject area, understanding of content, experience with game play, and participation in the class activities through the term. Examples of interview questions included: "What do you think about learning mathematics with Dimension M?"; "How has Dimension M helped you think differently about mathematics?"; and "How, if at all, has learning with Dimension M changed your interest in learning mathematics?" Videotapes and participant observation notes documented student actions as they engaged in game play and opportunities related to ICCE. Table 1 provides an example of the questions that guided the process of examining the ICCE opportunities in Dimension M.

Quantitative data included multiple-choice and short-answer knowledge test for mathematics with 32-items (see Table 2). To aid in item construction, the researchers played Dimension M before the start of the study using the TPACK

Table 1. Example of Questions for Examining ICCE Opportunities in Games

ICCE domain	Question
Inquiry	What is the nature of players' exploration of a particular topic/academic content in the game?
Communication	What kinds of feedback are provided for players?
Construction	What level of knowledge construction for the topic/academic content is possible in the game (content-only; content and application, but separate; content and application integrated—learning and doing is integrated well)?
Expression	What opportunities are available for players to feel connected personally through freedom of expression to learn, perform, and demonstrate *their* learning of the topic/academic content?

Table 2. Example of Items on the Mathematics Knowledge Test

Item
Over the past 8 years the property tax value of Jake's house increased from \$85,000 to \$93,000. By about what percent did the property tax value increase?
Simplify: $8\gamma^2 - 3\gamma - 5\gamma + 2\gamma^2$
The *x*-intercept of a line is the point on the graph where $y = 0$. What is the *x* intercept for the graph of $4\chi + 3\gamma = 12$?

framework as an analytical lens for determining the technological characteristics, pedagogical style, and the content that was embedded in the game. The classroom teacher and the researchers created the mathematics test based on school district standards for 9th grade and questions from the game database that supported those standards. It measured knowledge about algebra, roots, real numbers, and numbers and operations. Data sources also included a modified Likert-scaled survey for Intrinsic Motivation Inventory (IMI; Foster, 2011; McAuley, Duncan, & Tammen, 1987) with reliability of .71, and a Self Regulation Questionnaire (SRQ; Ryan & Connell, 1989) with reliability of .80.

Data Analysis

Since the study was of an intact classroom with a convenient sample of one classroom, we used SPSS to conduct a match-paired *t*-test to measure students mathematics knowledge gain and motivation. We also measured gender differences on mathematics gain and motivation to learn mathematics (intrinsic motivation) using multivariate analysis—MANCOVA. Pre-test scores were used as the covariate. The significance level for all tests was set at $p < .05$.

Qualitative analysis was used to triangulate and to explain students learning using grounded theory (Charmaz, 2006). Interviews and observations (video and field notes) were coded to document I-C-C-E opportunities that were: (a) embedded in Dimension M for engaging players in relevant learning goals; and (b) experienced by students for aiding their knowledge construction (foundational-, meta-, and humanistic-knowledge) and motivational valuing (personal interest, identity formation, self-regulation) of the mathematics content and skills.

Procedure

Prior to the start of the study, researchers and the teacher worked together to design the course, its curriculum and assessments, and to leverage the content embedded in Dimension M that was relevant to the course goals. At the start of the study, participants were introduced to the course objectives. Second, students completed pretests for knowledge and motivation assessments. This was followed by the PCaRD process, which characterized the weekly course intervention.

During the intervention period, at the beginning of classes, participants first engaged in naturalistic game *Play* for 30-40 minutes in each class from September to December. During this time they would engage in the opportunities of ICCE afforded by the game. Since not all games afford ICCE, students then engaged in *Curricular activities* designed by teachers to connect game play with learning goals for 20 minutes. An example would be a teacher downloading student log files, examining questions, and addressing problematic topics through classroom teaching. Students then engaged in *Reflection* activities for 15 minutes. These involved tying the curricular activities to students' understanding of the learning goals and their play experience, and by contextualizing that understanding to experiences in their lives. Reflection took place in web-blogs such that students could articulate their understanding to each other. The class would end with *Discussions* led by teachers and sometimes by students for 15 minutes. Discussions involved teachers examining students' reflection posts and addressing points of similarities and differences pertaining to student understanding and experiences from play-curricular activities- reflection. During PCaRD activities, students would engage in activities that provided opportunities for ICCE since they were not afforded in the game. Post-assessments were given 2 weeks before the end of the course in order to provide feedback to students.

Each week, two researchers aided the course activities as teachers and participant observers to model the game integration process through PCaRD and to record students play experiences through ICCE. This afforded great trust from the students and access to their learning experiences based on the integration process and game design. The teacher modeled the process in later weeks and he was especially good at facilitating student thinking about valuing and developing interest in mathematics. Interviews were conducted from the fourth week onwards to determine the ICCE efficacy of Dimension M.

RESULTS

First, we report the statistical findings for student gains in mathematics and motivation. Next, we describe how each component of ICCE was emphasized in Dimension M and in the teaching of the course through PCaRD. We report this through examples of student experiences of foundational-knowledge, metaknowledge, humanistic-knowledge construction, personal valuing, self-regulation, and identity formation for each component of the ICCE framework. We also briefly describe how ICCE opportunities were designed through PCaRD.

Quantitative Findings

Results from match-paired *t*-tests for the class indicated that students had statistically significant gains on the mathematics knowledge test as shown in Table 3.

On the surveys for motivation, there was an increase in students intrinsic interest to learn the mathematics content, but not at a statistically significant level. Students reported a decrease in self-regulation from pretest to posttest (see Tables 3 and 4).

Table 5 reports the group statistics; that is, the differences in female and male participants' mean scores on the knowledge test and motivation surveys. As depicted in Table 6, the test of between-subjects effects in MANCOVA indicated statistically significant gender differences on intrinsic motivation with $F(1, 18) = 16.815$, $p < .05$, but not on mathematics knowledge with $F(1, 18) = 0.158$, $p > .05$. In general, female students had a more favorable attitude to mathematics practice in the game.

Interpretive Findings

Broadly, Dimension M presented a drill and practice pedagogical approach to mathematics inquiry, offered a summative report of player performance, focused on content retrieval and encoding through multiple choice questions, and allowed some opportunities for expression. This impacted the students' learning process and their need to feel connected to the subject area. Classroom observations and interactions and interviews with students also informed the teachers' and

Table 3. Paired *t*-Tests Analysis of the Knowledge Test for the Overall Sample

Source	*df*	*t*	*p*	*d*
Pre-Post mathematics knowledge	18	4.70**	0.001	0.83*
Pre-Post motivation (IMI)	18	–3.77	0.170	0.30
Pre-Post self-regulation	17	–1.34	0.198	–0.34

Note: $p < .01$**; $R^2 = 0.39$.

Table 4. Descriptive Statistics of Mathematics, Intrinsic Motivation, Self-Regulation, Valuing and Perceived Competence

Source	*N*	PreMean	PreSD	PostMean	PostSD
Mathematics knowledge	19	13.53	3.52	16.68	4.01
Intrinsic motivation (IMI)	19	116.37	24.39	124.42	28.64
Self-regulation	18	105.67	22.20	98.83	17.66

Table 5. Group Statistics for Mathematics and Motivation

Source	Gender	*N*	Mean	*SD*	Std Err Mean
Pre-mathematics knowledge	M	8	14.75	3.845	1.359
	F	11	12.64	3.139	.947
Post-mathematics knowledge	M	8	17.88	3.643	1.288
	F	11	15.82	4.215	1.271
Pre-motivation	M	8	108.75	34.070	12.046
	F	11	121.91	13.330	4.019
Post-motivation	M	8	137.63	36.449	12.887
	F	11	114.82	17.480	5.271
Pre Self-regulation	M	8	94.0	25.84	9.135
	F	11	113.363	14.284	4.307
Post Self-regulation	M	8	96.625	19.877	7.027
	F	10	100.6	16.561	5.237

Table 6. MANCOVA Tests for Gender Differences for Mathematics and Motivation

Effect	Pillai's *T*-value	*F*	*df*	η^2	*p*
Gender*Motivation	0.529	16.815	1	0.73	.001
Gender*Mathematics	0.529	0.158	1	0.10	.697

Note: $p < .01$**; R^2 for mathematics = .55; R^2 for motivation = .70.

researchers' decisions to introduce curricular modifications through the PCaRD model.

How Does Dimension M Support Experiences of Inquiry for Learning?

Linear inquiry learning: Players mainly navigate within a 3D environment in a linear style for each of the four mini-missions in the game: Tower Storm, Velocity, Meltdown, and Swarm. Players race against time or opponents, collecting globes, shooting color-coded rings, and answering pop-up multiple-choice mathematics questions (see Figure 3).

For instance, in Tower Storm, a player first goes to a fountain to answer a multiple-choice mathematics question and collect a colored ball. Thereafter, the

Figure 3. Typical first person perspective of the 3D landscape in Dimension M.

player goes to a tower wrapped with rings and aims the ball on a matching colored ring. Scores are obtained only when the player answers the question correctly and collapses the matching ring. The following is an example of one student's description of the line of inquiry in a mini-game:

> We had to collect these little balls and then you have to activate it and then you have to go down in this little tunnel and that's where you have to answer the questions and if you get it right, I think you get like 200 points.

Inquiry emphasizing on gameplay not mathematics and gender differences: Overall observations revealed that most students' explorations within Dimension M focused on playing to improve their skills at beating the game (e.g., answering questions in a row to gain bonus points) and to gain a competitive edge over their peers (e.g., scoring the most points), but not on explicitly inquiring mathematical concepts encountered in Dimension M (e.g., practicing diverse concepts and skills). Initially, student experiences focused on understanding the purpose of Dimension M, learning the game controls for each mini-game, and navigating the game environment. As students gained comfort with game play, the focus shifted to championing game strategies to gain advantage over peers, beating personal and class records of highest points obtained, and establishing a lead position among peers. We found that whereas boys unanimously enjoyed the competitive nature of Dimension M, the girls expressed disinterest in it. However, during the course of the term, a few girls decided to join the boys and adapted to the performance approach of beating each other encouraged by Dimension M.

Gameplay detached from mathematical inquiry: As participants played Dimension M over the term, it became evident that gameplay actions and mathematics content inquiry were disconnected. Gooping, shooting, and color matching did not relate to multiple-choice questions or content such as square roots. The form of inquiry used in the game was constrained to drill and practice in all the mini-missions with questions sometimes repeating from the game database. Students expressed displeasure over the disconnection between mathematics learning and gameplay. This is illustrated in a student quote shared below as he compared learning mathematics in Dimension M with learning physics in a physics game in another term:

> Dimension M is a good game using math . . . but I like Physicus better. It teaches more about Science. Dimension [M] was like a game where you learn about Math through the questions it gives you, [whereas in] Physicus you find things about Science and its more related to Science than Dimension [M] is to Math.

Overcoming limitations of the game design through PCaRD pedagogy: During one *curricular activity*, with the objective of encouraging a mastery orientation among students, the mathematics teacher downloaded students' response and performance logs from the *Dimension M* game server. The teacher reviewed the underlying concepts and methods (e.g., reading the problems correctly) for working on these problems. Students were also encouraged to go back to their logs and reflect on their game-play actions, learning, and understanding of math on a regular basis.

How Does Dimension M Support Experiences of Communication for Learning?

Summative feedback on learner progress: The game primarily provides summative reporting on player performance. During game-play, the feedback given indicates whether an answer is correctly answered and the amount of time that is remaining to complete a mini-game. Upon completion, players are provided with an end-game report including the mission details (level, topic skill), question summary (number of answers attempted, number and percentage of questions correctly/incorrectly answered), and final scores (individual and team). The end-game report also includes a question and answer log which presents each question attempted by the player along with his/her answer on first attempt, second attempt (if allowed in the mini-game) and the correct answer.

Players can save the end-game report and review it to improve future performances. However, the performance summary does not provide suggestions for how to improve upon the mathematics concepts that students did not do well. As a result, most students chose to concentrate on their existing expertise.

Overcoming limitations of the game design through PCaRD pedagogy: Few students were observed motivating one another to keep pursuing game *play* and not quit it midway. For instance, in a group of three female students, one girl persistently encouraged her friends to play Dimension M. Her enthusiasm was a complete contrast to the latter's lack of interest in the game and mathematics. This process in turn benefitted the motivating female of the trio, whose performance in Dimension M grew steadily. The student kept challenging herself to better her performance and implicitly setting an example for her two friends. Towards the end, this student was among the highest performing girls in Dimension M. She managed to support and encourage her female friends to raise their performance from 0s to 25-100s to about 900.

Furthermore, in one *discussion* session, four high performing students were invited to share their experiences of playing Dimension M with the entire class. According to these four students, they worked together and strategized as a team. Tasks were divided according to individual strengths (as one answered the pop-up questions, the other killed/gooped opponents in Dimension M) and game features were exploited (avatar powers were activated). These four students believed they worked well because of their friendship and this allowed them to communicate and express their emotions with ease. This *discussion* encouraged all the students to heighten their engagement in the course activities to learn mathematics.

How Does Dimension M Support Experiences of Construction for Learning?

The game focused on quick retrieval of concepts by means of answering multiple-choice questions (see Figure 4). Players had opportunities to practice mathematics across three options: (a) mathematics levels including elementary, middle, and high school curriculum; (b) mathematics topics including algebra, data analysis and probability, geometry, measurement, number, and operations; (c) single, a combination, or a random mix of skills for a chosen topic and level.

Knowledge construction focused on content-only learning through drill and practice: Observations revealed that Dimension M focused mainly on foundational or content knowledge construction both in and after game completion. The end-game reports could be used as a potential resource for reflecting on students' performance; however, students were not explicitly encouraged by the game to review it in order to plan for future game plays. As a result, 95% of students' gameplay was on numbers and operation problems. The drill and practice method of the game may have resulted in students' statistical significant mathematics gains; however, students were not intrinsically motivated to learn the mathematics or play the game. Students were bored and felt that the mathematics questions from the game database became redundant.

Mathematics learning disconnected from learners personal and pedagogical experiences: In-class interviews revealed that mathematics learning in Dimension M was decontextualized like in school, resulting in students who were high performing, but low on interest. During one such occasion, a student declared that although he was good at mathematics, and did not guess to solve problems in the game, he did not like mathematics and found it boring. For the student, mathematics instruction was without any objective and disconnected from the realities of life (e.g., money, job), thus creating a dislike for the subject. Retaining the difficulty level and grounding it in realistic examples would make mathematics fun to understand for all students, expressed this student.

Overcoming limitations of the game design through PCaRD pedagogy: The objective of Dimension M was to make players practice mathematical concepts rapidly through multiple-choice questions. However, the game lacked procedural and conditional feedback that would allow players to perform better and smarter. Interactions with students during *play* allowed the researchers to overcome this limitation of Dimension M and support students' knowledge construction:

> *Student:* The problem [is that] when you're doing the math, you got to answer and you don't know how to figure it out. . . . There are two answers . . . to trick you . . . they make it look similar. There is always a right one and you don't know which one to pick.

Figure 4. Typical pop-up mathematics question encountered during gameplay.

> *Researcher:* [Student's] problem is something that is fundamental with multiple-choice questions. There is always one choice that is so close to the right answer. How do you deal with that?
>
> *Researcher:* So, if you have a multiple-choice question, and one choice seems obviously wrong, it is wrong! The other issue was also that there is usually one answer that is too close to the right answer. But there is a difference. And there is only one way to overcome that. You've just got to know how to solve the problem. Guessing won't help you. It's a 50-50% chance if you guess. But you want to increase your odds. You want a 100% chance.
>
> *Researcher:* But usually, you can eliminate one or two answers immediately because [those are] nonsense answers. You're left with two possible answers. Don't guess. Try to solve the problem. Don't leave it [unanswered].

How Does Dimension M Support Experiences of Expression for Learning?

Inadequate avenues of expression: The game allowed players to customize the features of their character avatar. However, in the study, 90% of the students were disappointed with the characters in Dimension M because they felt the avatars were unrepresentative of them, looked too mechanical, and could not be modified to fit their needs. The female participants felt that the avatars were too masculine and this hindered what they believed about themselves as female students who can do mathematics. In addition, in a class of mostly minority students, the avatars also did not reflect their ethnic origins. The inability to emotionally connect with the game affected students and lessened their motivation for learning mathematics in Dimension M as a game.

Overcoming limitations of the game design through PCaRD pedagogy: Researchers created a *reflective* activity called "avatar design" to facilitate student academic identity and to help them overcome their motivational obstructions to learn. This activity allowed students to draw their own new avatars with colored markers and pencils on paper that they could relate to and which connected to their sense of self as it related to them learning mathematics and their identity. Overall, students commented that their newly designed avatars, which were external to the game, provided a sense of strength and vulnerability that influenced their gameplay and motivation to play because it empowered them. They projected the strengths and weaknesses of their real self and melded that self with the preferred skills of the virtual avatar. For example, one student commented that:

> My avatar is basically like Barak Obama . . . I want my avatar to symbolize something like Barack Obama to help people out. In the game, instead of scoring points, I'm looking to help people or just to have fun. I want . . . a power that can lead. I want to help people.

Students named their avatars Obama56, KrisyBritish1876, Prissy, or DarkSide, which reflected students' academic values and racial and cultural identities (see Figures 5 and 6).

In general, as with the example in Figure 5, the avatars did not represent students' current self-concept of lacking mathematical skills, only their goals. The avatar in Figure 6 also represented taking on a leaders identity, seeing self as being able to help others learn mathematics even if the real self might not be the most competent mathematics learner.

Synthesizing Results

Several factors affected students' play and the change in their mathematics knowledge and motivation to learn mathematics. These included the following: their first experience with a game-based learning course, their dislike for the subject area, and the design of the game which was not the best for learning mathematics in an interesting and engaging way for these students. The linear approach and performance orientation of Dimension M did not sustain students' motivation to learn mathematics through a game. Dimension M provided players with an opportunity to practice mathematics concepts, which allowed students to make knowledge gains. However, the game lacked explicit construction and communication opportunities to develop self-regulation and meta-cognition among

Figure 5. Avatar possessed the attributes of a smart and beautiful mathematics student as a reflection of a female student's goal.

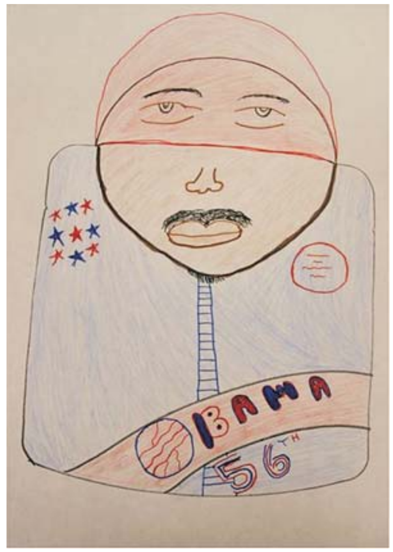

Figure 6. Avatar possessed the attributes of a patriot in the colors and symbols used.

players. Finally, Dimension M did not present students with an opportunity to feel personally connected and immersed in doing mathematics in an authentic context. Students explained that the mathematics practice and the game play were disconnected. They practiced enough to gain mathematics knowledge, but the design of game play was not engaging to the point of valuing and developing interest in mathematics.

DISCUSSION

Dimension M was analyzed using the inquiry, communication, construction, and expression (ICCE) framework. The ICCE framework allowed the researchers to address recommendations from studies that have previously used Dimension M with high school students (Kebritchi et al., 2010; Ritzhaupt et al., 2009) and gaps identified in the field by leading scholars (Steinkuehler & Squire, 2014) by: (a) understanding the learning experiences the game afforded; and (b) explaining the effect of the Dimension M on 20 9th grade students' knowledge construction and motivation to learn mathematics in a game-based learning course. Dimension M had a drill and practice pedagogical style for learning mathematics. It provided a common approach for all players to engage in mathematical inquiry, feedback that was focused on improving students' performance in a specified curriculum but lacked meta-cognitive coaching, and insufficient opportunities for expressing oneself. Thus, although students made significant gains on the knowledge test, they did not value the learning of mathematics and did not like learning mathematics in the game.

The ICCE framework provided a lens for assessing the educational merit of Dimension M from a Deweyan perspective (Bruce & Levin, 1997; Dewey, 1956) along several learning dimensions such as affect, cognition, motivation, and pedagogy (Killi, 2005; Mitgutsch & Alvarado, 2012; Rice, 2007). Dimension M mainly encouraged a goal seeker player type. A player type is an amalgamation of player's play style and motivational orientation to learning (Foster, 2011). Specifically, owing to the design of Dimension M in terms of ICCE, most participants in this study tended to focus less on exploring and honing their skills in mathematics, usually doing just enough to beat the game and their peers. Exploration was only limited to the initial weeks when the students were learning how to play the game, but rarely related to mathematical learning. Further, there was an absence of a relevant context in Dimension M to learn mathematics, which obstructed students' need to feel connected to the subject area. In addition, the scaffolding in learners zone of proximal development (Vygotsky, 1978) was not met as players focused on their current expertise level and did not strive to advance.

The Play Curricular activity Reflection Discussion (PCaRD) model allowed the teacher and the researchers to leverage the strengths of Dimension M and design opportunities for ICCE that were lacking in the game. Play provided naturalistic opportunities to observe the ICCE opportunities students were engaging in in Dimension M and learn about their motivational obstructions to learning mathematics in school and through the game. During the curricular activities, reflection, and discussion activities, the game features (e.g., performance logs), student interactions (peer-peer, student-teacher), student interests (e.g., avatar, competition) were used as anchors to scaffold student knowledge construction and motivation, and thus accomplish the course objectives.

CONCLUSION AND IMPLICATIONS

The inquiry communication construction and expression (ICCE) framework was developed in response to a dearth of approaches to assess games for learner experiences. This gap has impeded educators', researchers', and game-designers' capacity to improve learning experiences and the efficacy of games for supporting students (Young et al., 2012). Thus, the ICCE framework is an approach for: (a) educators and game designers to understand the learning opportunities afforded in game environments (Shaffer et al., 2005); (b) researchers to demonstrate to educators how instructional affordances within games can support the attainment of learning objectives and to game designers how instruction can be effectively integrated within the design of games (Tobias & Fletcher, 2012); and (c) educators to identify the implicit pedagogical stance and embedded content in a game for using the technology effectively for teaching and learning (Foster & Mishra, 2009).

Researchers should continue to examine games for transformative learning and the opportunities for ICCE experiences through direct observations or personal experiences of game play (Aarseth, 2003). Researchers should also include ICCE to enhance reporting practices in game-based learning studies (Ritzhaupt et al., 2014). Long-term investigations with larger sample size are further recommended.

The ICCE framework is nested in a larger framework known as the Game Network Analysis (GaNA), which was developed for enabling teachers and researchers in introducing game-based learning in classrooms by guiding them in game analysis and game integration within an existing or a new curriculum (Foster, 2012). The ICCE framework bridges game analysis and game integration by identifying learning opportunities and designing opportunities that may be lacking in a game. This article reported on the role ICCE played as a method to identify learning experiences in games and highlighted the use of PCaRD. The objective is not to use ICCE to judge any game as good or bad; rather, the significance of ICCE is in its use as a framework for determining if a game has all ICCE components to support learners.

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