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Computer game development as a literacy activity

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ABSTRACT

This study examined computer game development as a pedagogical activity to motivate and engage students in curriculum-related literacy activities. We hypothesized that as a consequence, students would improve their traditional reading and writing skills as well as develop new digital literacy skills. Eighteen classes of grade 4 students were assigned to either an experimental or control group. Both groups studied the same curriculum unit over a 10 week period, however, in addition the experimental group developed computer games related to the unit using a game development shell. An analysis of pre- and post-unit scores on two standardized literacy test batteries revealed that the experimental students performed significantly better on one of the subtests, a measure of Logical Sentence construction ($p = .002$). Field notes and teacher interview data indicated that game development helped improve student content retention, ability to compare and contrast information presented, utilize more and different kinds of research materials including digital resources, editing skills, and develop an insight into questioning skills.

1. Introduction

Contemporary notions of literacy now extend beyond traditional print formats, and a rethinking of the kinds of literacy skills that will be required for full social and economic participation in the 21st century is well under way. Yet schools for the most part still view literacy from a traditional perspective (Castells, 2000; Tyner, 1998). Outside of school the new generation of learners, frequently referred to as 'digital natives' (Prensky, 2006), are regularly immersed in a wide variety of new electronic media and as a consequence are developing knowledge and skills that increasingly diverge from those that are valued in school (Lankshear & Knobel, 2006). In light of these dramatic changes and because of the failure of schools to respond, prominent educational and media researchers are calling for the revision of traditional pen-and-paper curricula to include multiple media for the representation, production, and dissemination of knowledge (Cope & Kalantzis, 2000; Kress, 2003; New London Group, 1996). Advocates of this perspective contend that schools must be the primary agents of change that take the lead in revising the old curricula and providing students with opportunities to extend their repertoire of literacies to better prepare them to be competitive and responsible citizens in the new millennium (Kellner, 2004). A recent report by the government-appointed Ontario Expert Panel on Literacy, for example, acknowledges that education needs to take into account the changes in literacy requirements, and present students with a range of texts that move beyond print to incorporate multi- and hypermedia (Ontario Ministry of Education, 2004). The Federation of American Scientists' Summit on Educational Games concludes that "educational institutions need to transform their organizational systems and instructional practices to take greater advantage of new technology, including educational games" (Federation of American Scientists (FAS), 2006, p. 46).

Among the many media artifacts of the digital era computer and console games stand out as examples of a tremendously popular and successful media. According to Rideout, Roberts, and Foehr (2005), "more than eight in ten (83%) young people have a video game console at home, and a majority (56%) have two or more" (p. 36). Video and online game production is a multi-billion dollar industry whose profits reached 7.4 billion dollars in 2006 (Entertainment Software Association, 2007). Indeed, computer gaming is more frequently chosen by young people as a recreational activity than watching television (Squire, Giovanetto, Devane, & Durga, 2005). By the time an average American turns 21, he or she will have spent 10,000 h playing computer games (Prensky, 2006).

Computer games, being a popular and familiar medium to most young learners, present an attractive and efficient means to bring new forms of contemporary digital literacies into the curriculum. Educational theorists argue that gaming embodies a new kind of literacy (Gee, 2003; Squire et al., 2005), one that combines significant elements of traditional reading and writing with new literacies that pertain to accessing and evaluating information, constructing complex narratives, decision-making, and navigating rich multimedia environments

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(Beavis, 2002; Lotherington, 2004). In addition, massively multiplayer online games such as *World of Warcraft* are seen as a potentially powerful vehicle for developing the new set of digital literacies required to navigate the digital world (Steinkuehler, in press). Playing and (especially) developing online games can allow students to access and engage with digital media and explore them, both independently and cooperatively. This exploration fosters the emergence and development of digital metaliteracies—skills which include navigating and 'reading' digital environments, as well as developing an understanding of the digitally-connected audience, and searching for information online (Lotherington, 2004).

The growing gap between the increasing sophistication and attractiveness of commercial gaming and the relatively static practices of school-based learning have led scholars to challenge the current state of technology use in schools. Squire and colleagues, for example, ask "How will educational technologies respond to a generation of students who, raised on interactive games, expect the same kind of interactive experiences from their educational media?" (Squire et al., 2005, p. 34). To address the need to develop both traditional and the newer, digital forms of literacy in students within a school setting, and to more fully engage students through interactive learning experiences, we conducted an experimental study to examine the effects of student online computer game development on literacy skill acquisition. Students researched and developed curriculum-based questions which they then incorporated into electronic versions of popular board games. Once students completed their games, they shared them with other students in their class to play. Students in the control group completed the identical curriculum although they did not develop or play games.

1.1. Games and learning

The strong, widespread appeal of computer and console gaming to today's students has motivated a number of researchers to look for meaningful ways to understand the principles behind learning through games, so as to better harness the educational potential of gaming (de Castell & Jenson, 2003). Prominent educational theorists have argued that successful recreational games employ many principles of effective learning (FAS, 2006; Gee, 2003; Mitchell & Savill-Smith, 2004; Prensky, 2006). Games create opportunities for situated learning by providing immersive and motivating contexts for players to engage in a wide variety of activities and to develop and practice the skills necessary to be successful in those activities (Gee, 2003; Shaffer, Squire, Halverson, & Gee, 2005). A number of attributes common to computer games are recognized as critical in fostering active engagement, motivation, and high levels of persistence in game play (see Garris, Ahlers, and Driskell (2002) for a more complete review). These include the use of high resolution media to create immersive environments and simulate quasi-realistic sensory experiences for the players (Mitchell & Savill-Smith, 2004); providing opportunities for identity exploration and play through the inclusion of fantasy, narrative, and role-playing (Gee, 2003; Squire et al., 2003); and creating a sense of pride and accomplishment through structuring the game play in complex ways that will challenge the player at the "edge of their region of competence" and allow for progress through trial-and-error experimentation (Gee, 2003). Successful games support players through creating scaffolds, or built-in cues, hints, and practical solutions to keep them immersed in the game (FAS, 2006).

The motivational power of the best games keeps players involved in them for many hours, and their game play designs allow players to experience flow—a state of optimal engagement characterized by a deep immersion into an activity, accompanied by heightened concentration, motivation, and sense of fulfillment (Csikszentmihalyi, 1991; Inal & Cagiltay, 2007). Researchers have noted that the social aspect of collaborative or competitive game play fosters learning through team-playing (Mitchell & Savill-Smith, 2004) and group problem-solving (Kiili, 2007), and offers opportunities for players to cooperate not only within the game, but also within the larger community of the game's fans through websites and online forums (Shaffer et al., 2005).

If computer games are to find their way into regular schooling and be supported by the broader educational community, systematic and multi-faceted research on their effectiveness needs to be undertaken (FAS, 2006). To date, there is insufficient research beyond anecdotal evidence that would support game use in the classroom (Bonk & Dennen, 2004; Dempsey, Haynes, Lucassen, & Casey, 2002; Gredler, 2004). A series of early experimental studies looked at the impact of specific game and simulation attributes on student motivation, learning performance, and perceived self-efficacy (Cordova & Lepper, 1996; Parker & Lepper, 1992). These studies identified four key factors that contributed to increasing student motivation and engagement in learning: the provision of a narrative context for the game; the incorporation of fantasy elements in a game; the inclusion of opportunities for players to make choices during game play; and the provision of opportunities for the incidental personalization of the game activity by the player.

More recently, several qualitative case studies investigated the educational potential of gaming. McFarlane, Sparrowhawk, and Heald (2002) conducted an evaluation of educationally relevant commercial and 'edutainment' games in 12 elementary schools. They found that while playing these games students engaged in deductive reasoning, collaborative problem-solving, cooperative learning, and peer-tutoring. Teachers in the study saw several educational benefits to the use of the games, including developing students' communicative, collaborative, and strategic-planning skills. In a similar study six different games were deployed in 11 secondary schools in Britain (Becta, 2001). The study reported that gaming promoted learning very effectively through combining high interactivity with an appealing and novel narrative context. Additionally, student motivation, collaboration, and task persistence were high, and there was evidence of social construction of knowledge.

1.2. Games, engagement, and literacy

Collectively, the initial research findings on educational gaming suggest that it has a place in classroom instruction, and can be used to facilitate learning in multiple ways. Perhaps most importantly, it can be a vehicle for increasing motivation and engagement. Student engagement is a crucial element in academic achievement, and especially so in relation to reading and literacy (Learning Point Associates, 2005). Studies have shown that academic achievement is associated with engagement in reading and classroom-related activities (Finn & Rock, 1997). With regard to students-at-risk, high engagement in reading results in better reading scores for students of lower socio-economic status compared with less engaged students of higher status (Kirsch et al., 2002). Since entertainment games appear to be an extremely successful means of motivating and engaging youth, it seems reasonable to contend that given properly designed educational gaming media, much of this motivating power could be harnessed in formal literacy instruction. Game use in the classroom could provide or develop many of the components and factors that research has found to be related to literacy development: the provision to students of relevant and interesting material (Greenleaf, Jimenez, & Roller, 2002); the heightening of student self-confidence and control of their own

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actions (which students so often lack at school) (Alverman, 2003); and greater student involvement in reading (Baker & Wigfield, 1999) and collaboration (Guthrie et al., 2007). Some initial evidence for this contention can be found in a recent study investigating the instructional use of gaming showed which students playing games experience flow, are immersed in learning, and have increased time-on-task which leads to better learning (Inal & Cagiltay, 2007).

There are no published studies to date on the effects of computer game development—as opposed to game play—as a pedagogical activity in the classroom. Giving students opportunities to input their own content into a game can be a powerful motivational tool that contributes to a sense of pride and accomplishment, and facilitates learning (Gee, 2003). The primary roadblock to utilizing game design for learning in a school context is the lack of expertise on the part of students and teachers who do not possess the complex skills required to create computer games. A solution to this problem lies in using a web-based game shell such as the one employed in the present study. Game shells do not require any sophisticated hardware or software, and developers do not need to perform complex programming tasks in order to create games using these shells.

The game shell used in this study effectively combines elements of familiar board games with the interactivity and appeal of contemporary online games. Board games have been recognized as tools for early literacy development (Saracho, 2000, 2002). Researchers argue that forming a positive attitude towards reading and literacy through playful and entertaining activities, such as board-game playing, helps develop avid readers (Sonnnerschein, Baker, Serpell, & Schmidt, 2000). Board games have been used successfully in primary school research for fostering group learning and collaboration in literacy skills development (Lyle, 1999). Lyle (2000) found that student literacy skills were enhanced by teaching geography using a range of literacy-specific activities including creating a board game. She argues that writing game instructions and creating game cards fosters development of writing skills and engenders student enthusiasm. In a project focused on literacy development in an after-school playground that combined electronic and board games, Blanton, Greene, and Cole (1999) found that playing board games is associated with developing literacy and essential learning skills, including language comprehension, social skills required for collaborative learning, and task persistence.

In order to foster literacy skills, the game development activities selected for this study had a strong language component. Students developed web-based board games by inputting series of question into game shells. We hypothesized that creating curriculum-based game questions would be a literacy-rich task that would allow students to engage in reading and writing while staying engaged in a motivating gaming activity. There is ample evidence that questioning as an instructional activity increases students' comprehension and literacy skill (Rosenshine, Meister, & Chapman, 1996). Wong (1985) discusses the instructional merits of using student-generated questions in reading, which include active processing of the material, activation of prior knowledge, and improving students' metacognitive skills. Lubliner (2004) found that individual instruction of struggling fifth grade students in generating questions resulted in improved reading comprehension. Additionally, King (1994) reports that using a collaborative questioning strategy improved student comprehension for grade 4 and 5 students who generated and answered their own and each other's questions.

1.3. Research questions

To summarize, there is considerable theoretical and evidentiary support for the contention that game playing has the potential to increase student engagement in school activities, their task persistence, and their motivation to learn, and that these factors then serve to mediate improved achievement, as well as promote the development of collaborative skills and social learning strategies. The development of online computer games using shells based on popular board games holds promise as a pedagogical activity that can foster the development of traditional reading and writing skills as well as new digital literacy skills. Therefore, we chose to investigate four research questions in this study: (1) Can computer game development as a pedagogical activity lead to improved learning of basic literacy skills? (2) What new digital literacy skills do students acquire as a result of this activity? (3) What is the impact of game development on student classroom engagement? (4) How do teachers adopt and shape the practice of student game development in the classroom?

2. Method

2.1. Research design

We conducted the study in the grade 4 classrooms of nine public elementary schools in south-central Ontario, Canada. The schools were located in middle or lower-middle income suburban neighborhoods. On the annual province-wide language proficiency test taken at the end of the previous year in grade 3, an average of 68% of these students met the provincial standard for reading and 70% met the standard for writing. Given that the comparable province-wide rates were 62% and 64%, respectively, as a group the students in our study scored moderately above average in measured language proficiency (http://www.eqao.com).

Each participating school had either two grade 4 classrooms or only one grade 4 classroom plus another classroom containing students from both grades 3 and 4. In each school a classroom was randomly assigned to either the experimental (game playing) group or a control group. The randomization criterion was the teacher whose surname was closest to the beginning of the alphabet became the experimental group. Thus the study began with a total of nine experimental classrooms and nine control classrooms.

At the beginning of the study we held a half day workshop to introduce teachers to the purpose of the study, show them how to use the game development shell *Education Games Central*, and guide them in how to teach the social studies curriculum unit *Tracks Across Canada* that we developed specifically for this project. (The game shell and curriculum unit are described below.) Shortly afterwards, all teachers began implementing the curriculum unit. Teachers in the experimental group took time to teach a lesson on the construction of effective questions with an emphasis on helping students develop higher level, inferential thinking questions rather than simple factual recall questions. Then the experimental group teachers introduced students to the game shell and asked them to make, in pairs, a *TicTacToe* game based on their interests to get them familiar with the shell. Typically, students chose to make games related to sports or their hobbies. Once students became familiar with the tool, teachers asked them to make a *TicTacToe* game related to the first lesson of the curriculum unit. To do this, students were asked first to do research on their game topic, using either print materials or the Internet. Next they were to compose questions about various aspects of their topic. Questions for this, and subsequent games, could be in True–False, Fill-in-the-Blank, or

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Multiple Choice format. In some cases students wrote their questions by hand and transcribed them into the computer later, while other students entered them directly into the computer. When students finished their games they played each others' games. As the teaching of the unit progressed, teachers in the experimental group asked students to develop games for each of the three remaining lessons of the unit using the *Trivia*, *Snakes and Ladders*, and *Mother Goose* game shells, respectively.

Teachers in both groups spent on average one hour per week over 10 weeks to teach the unit and have their children complete all unit activities. Experimental teachers took approximately the same amount of additional time over the 10 week period for game construction and playing. Game activities took place in school computer labs except for one school where students had laptop computers with a wireless Internet connection. Eight of the nine schools that began the study completed all required activities. The one school that dropped out had the same teacher teaching social studies to both the control and experimental groups. This teacher felt that the unit and game activities were too demanding of her time as she got behind in the project due to illness and because her students were not very strong academically. We obtained complete data sets for 125 experimental group students (60 female, 65 male) and 186 control group students (90 female, 96 male). These data sets contained scores on all pre- and post-study measures which we describe below. The discrepancy in group sizes was because several experimental classes also contained students from grade 3 who did not participate in the study.

Throughout the study a member of the research team visited each school at least once to ensure the experimental program was being implemented as designed, observe game construction, informally interview the teachers and students, and take field notes. We chose two of the participating schools for more detailed study and made a total of five visits to each. After the project's end we held a half day debriefing workshop for control and experimental teachers. In addition to getting feedback from the group as a whole, we interviewed the experimental teachers in small groups about their experiences with the study. While these interviews were taking place, another research team member introduced the control teachers to the game shell as we had promised them later access to this as an incentive to get control teachers to participate.

2.2. Game shell

Education Games Central (http://egc.savie.ca/) was the game shell we used in the study. This web-based shell simplifies the construction of electronic versions of popular board games. To create a game, students need only develop a set of questions and answers and enter them into online forms. Each game requires a different minimum number of questions for the game to function properly: *TicTacToe* needs 16 questions; *Snakes and Ladders* needs 27 questions; *Mother Goose* needs 44 questions, and *Trivia* needs 54 questions. Game developers have the option of specifying the feedback a player receives when a question is correctly or incorrectly answered. They can also embed links to web resources in the questions. A step-by-step wizard-like guide down the left side of the game creation page verifies whether all questions are entered correctly and if the game is ready to play. Fig. 1 illustrates a question creation page. When playing the game, players are

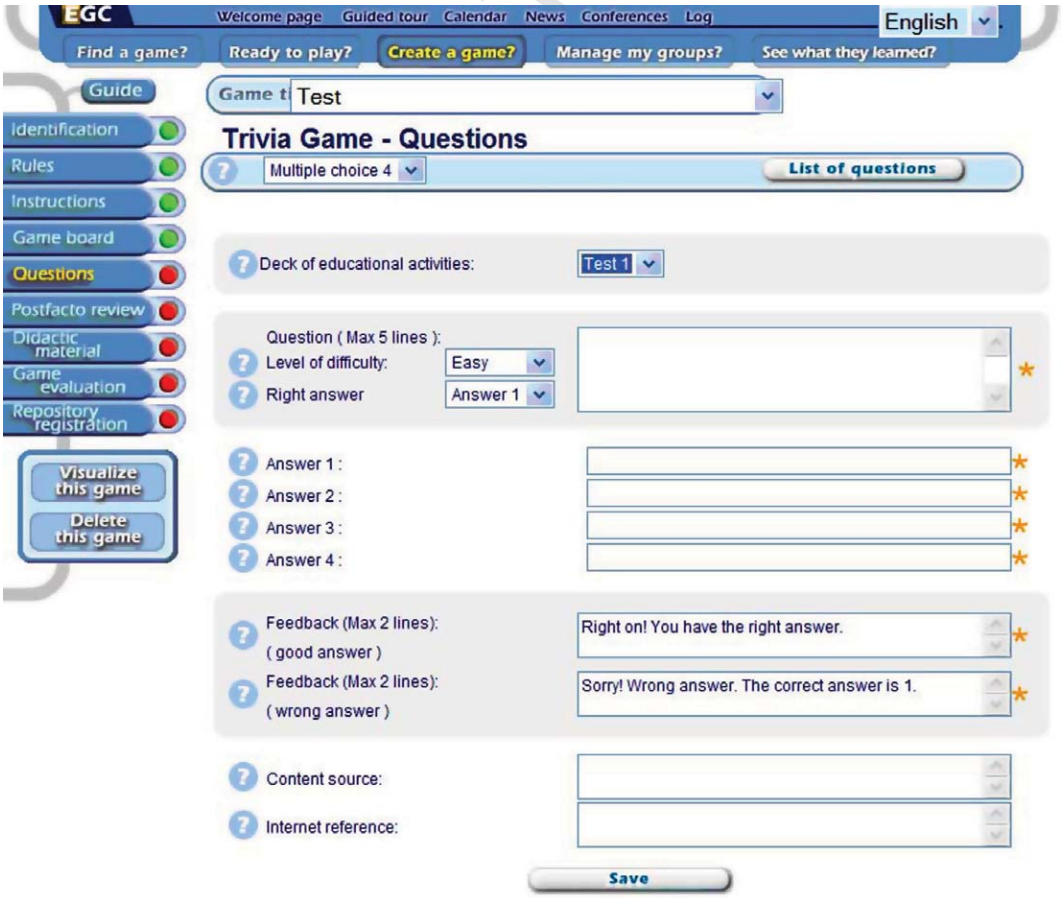

Fig. 1.

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presented with a question from the game which they must answer correctly before advancing on the game board. Fig. 2 shows a *TicTacToe* game developed by a student in this study.

2.3. Curriculum unit

The *Tracks Across Canada* curriculum unit developed for this study was aligned with the Ontario grade 4 social studies curriculum for teaching the mandated topic Regions of Canada. Although the unit dealt with a social studies topic, it was designed to be cross-curricular by incorporating activities that address the Ontario mathematics, science, language arts, and communications learning expectations. The unit has students read a children's book about a fictional character as he travels across Canada. As students read the book they learned about the location and characteristics of the physical regions of the county, and investigated the exchange of goods and services between the regions. The unit has five lessons and at the end of each lesson (except lesson 4 which was short) students in the experimental group were asked create a specific type of game for each topic as follows:

Lesson 1. Topic: Introduction to the unit. Game: *TicTacToe*.
Lesson 2. Topic: Researching a Canadian region. Game: *Trivia*.
Lesson 3. Topic: What is a map? Game: *Snakes and Ladders*.
Lesson 4. Topic: Presentation of research. Game: none.
Lesson 5. Topic: Regional arts and culture: Game: *Mother Goose*.

At the beginning of this section, the general task students in the experimental group were asked to do for game construction was described. To illustrate this in more detail, consider Lesson 3: What is a map? in which students were required to create a *Snakes and Ladders* game. This lesson introduces students to key concepts about maps such as the four cardinal directions, scale, legends, symbols, longitude and latitude, and use of color to indicate features. After students learned about these concepts though direct instruction from the teacher and from hands-on exploration of maps, they began their game activity. This activity required students to do additional research, with one or two partners, on the key concepts if they did not understand them fully, or to find examples of the concepts to help them with question creation. This was typically done by doing a Google search of the concepts and/or by visiting websites recommended by teachers (which they got from the unit plan). While they were doing their research students were began to formulate questions for the game shell. At least 27 were required in this case for *Snakes and Ladders*. In addition to practicing Internet and text-based research skills, the literacy skills students needed for the activity included: the ability to read the research materials for detailed understanding; employ new technical vocabulary; compose questions that were concise, readable, and understandable by others; think creatively, logically, and brainstorm; ensure that sentence spelling and punctuation of questions were correct; write plausible distractors for multiple choice questions; and compose the stems of True–False questions that were plausible but false. When students were ready to enter their questions into the game shell, they had to learn how to access a particular website and navigate to the appropriate page for the game shell they were using, learn step-by-step procedures for question entry into the new software tool, debug their question entries if they got an error message, and test the operation of their games. Thus, by developing games for the curriculum unit, students needed to learn or improve a many traditional as well as new digital literacy skills.

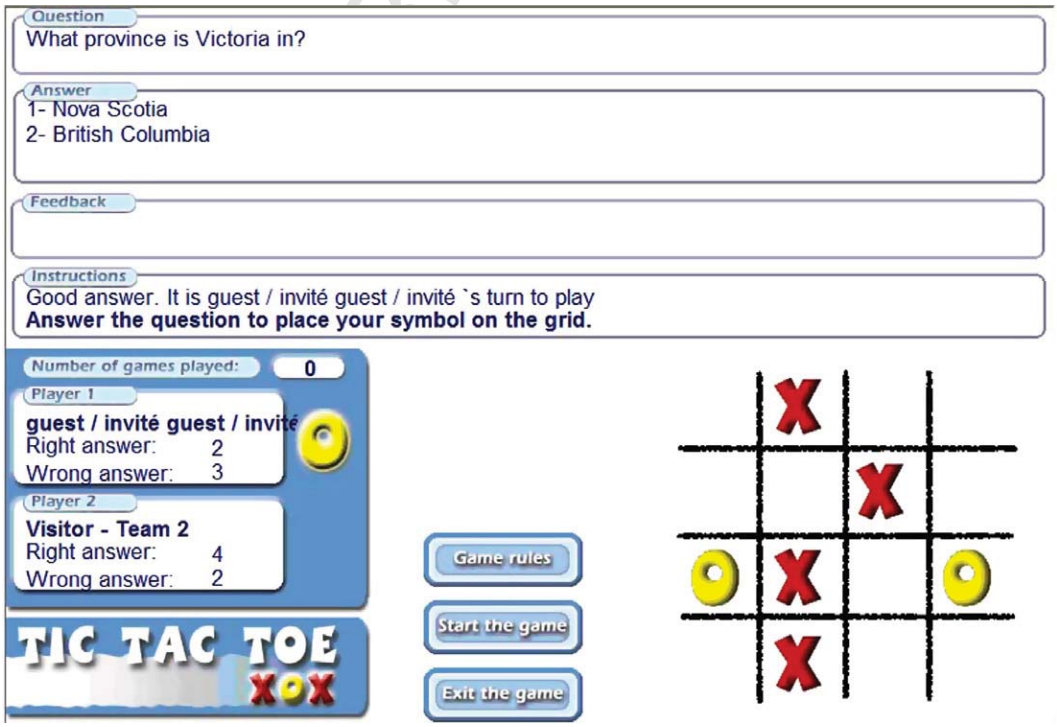

Fig. 2.

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2.4. Instruments

At the beginning of the study teachers administered to all students Form A, Level 4, of the Group Reading Assessment and Diagnostic Evaluation (GRADE) (American Guidance Service, 2001) to assess their initial basic literacy skills. At the end of the study, they administered the same subtests of Form B, Level 4, of the GRADE. The instrument has four subtests: Vocabulary, Sentence Comprehension, Passage Comprehension, and Listening Comprehension, but we asked teachers to administer only the first three subtests as the fourth was not relevant to this study. The Vocabulary subtest requires the student to read short sentences in which one word in printed in bold and pick the meaning of the word from a list of five choices. The Sentence Comprehension subtest consists of sentences in which one word is missing and the student is required to pick the missing word from a list of five choices. The Passage Comprehension subtest requires the student to read short paragraphs and answer multiple choice questions about the passages. Split-half reliabilities of the subtests of the two forms range from 0.92 to 0.94; the test–retest correlation between the forms is 0.87.

In addition to administering the GRADE test at the end of the study, teachers gave students three subtests of an adapted version of the Test of Written Language, version 3 (TOWL-3) (PRO-ED, n.d.). We refer to this test as the Student Writing Test (SWT). The subtests of the SWT adapted were: Vocabulary, which asks the student to write sentences incorporating a stimulus word; Sentence Combining, which asks the student to integrate the meaning of several short sentences into one grammatically correct written sentence; and Logical Sentences, which asks the student to read an illogical sentence and then edit the sentence so that it makes better sense. We adapted the content of the subtests to better reflect the content and vocabulary of the unit being taught. For example, in the Vocabulary test students had to write sentences containing nouns employed in the unit such as salty, melt, shield, and crop. In the Sentence Combining test students had to combine the two sentences "Snow is white. Snow is cold" into one sentence. And in the Logical Sentences test students had to correct the illogicality in the sentence "I would like to see the Atlantic Ocean but I have never been to the west coast." (The Atlantic is on the east coast of Canada.) The inter-rater reliabilities for scoring the Vocabulary, Sentence Combining, and Logical Sentences tests are 0.96, 0.88, and 0.88, respectively (PRO-ED, n.d.).

2.5. Data analysis

We analyzed GRADE test scores using a repeated measures MANOVA design contrasting the experimental and control groups. The two groups were also contrasted using their SWT test scores as dependent variables, with their pre-test GRADE scores serving as covariates in an ANCOVA analysis. The SPSS statistical software package was employed for the quantitative analyses.

Analysis of the qualitative data, which included field notes and transcripts of teacher interviews, began with the coding of these data with codes derived from the four research questions given above. From these initial categories, we generated subcategories inductively using the constant comparative method described by Bogdan and Biklen (1998). This process involved examining the data for key issues, recurrent events, or practices that then became tentative subcategories of interest. The data were then further examined to look for confirmatory or contradictory evidence of the subcategories and whether addition subcategories were needed. Once we were satisfied that all data were accounted for we wrote summaries of the subcategories which became the basis of the qualitative write-up. For the coding and analysis we used the qualitative data analysis software package Atlas.ti (http://atlasti.com).

3. Findings

Teachers taught the unit as planned and students in the experimental group developed games according to the research protocols. Students created a total of 285 games during the study, although there was considerable variation in the number of games produced by different classes. The median number of games created per class was 31, while the most productive class developed 54 games and the least productive class developed 20 games. These games contained a total of 7199 questions. The number of questions written per class ranged from a low 276 to a high of 1738 with a median of 726 questions. In the following sections, we describe our findings on the four research questions.

3.1. Impact of game development on basic literacy skills

The pre- and post-test means, standard deviations, and subject counts for the experimental and control students on the three GRADE subtests employed (Vocabulary, Sentence Comprehension, and Passage Comprehension) are given in Table 1.

Table 1
GRADE subtest scores: Descriptive statistics by student group.

GRADE subtest	Group[a]	Mean	Standard deviation	*N*
Vocabulary – pre-test	C	22.7	6.9	125
	E	22.3	7.6	186
Vocabulary – post-test	C	22.5	7.8	125
	E	23.0	8.0	186
Passage Comprehension – pre-test	C	17.2	6.9	125
	E	18.2	6.9	186
Passage Comprehension – post-test	C	16.4	8.3	125
	E	17.5	7.0	186
Sentence Comprehension – pre-test	C	14.0	4.2	125
	E	14.5	4.1	186
Sentence Comprehension – post-test	C	15.1	4.0	125
	E	15.3	3.5	186

[a] C, control; E, experimental.

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A repeated measures MANOVA on the test results contrasting the experimental and control groups did not find a significant multivariate effect for the time (pre-test–post-test) by group (experimental–control) interaction ($F(3, 307) = 1.09$, $p = .35$), indicating that taken together the three subscale measures showed no significant difference between the experimental and control groups in terms of their pre/post-test GRADE score differences (change scores). Further analysis by gender was planned but not carried out because the post hoc statistical power of the design was .294 which was too low to detect any intra group differences.

The test means, standard deviations, and subject counts for the experimental and control students on the three Student Writing Test (SWT) subtests (Vocabulary, Logical Sentences, and Sentence Combining) are given in Table 2.

A multivariate ANCOVA was run using the three post-treatment SWT subscale measures as dependent variables and the three GRADE pre-test subscale scores as covariates to control for general literacy differences between the experimental and control groups. The results of the multivariate test were significant ($F(3, 299) = 15.18$, $p = .002$), which indicates that the students in the experimental group performed significantly better on the SWT when the subtests are analyzed together. The multivariate effect size (partial Eta squared = .05) revealed that the mean inter-group difference was relatively minor, however. No significant differences were found between genders.

Univariate tests using the same set of covariates showed only the Logical Sentences subtest to be significantly different across groups ($F(1, 301) = 9.55$, $p = .002$), with the experimental group achieving a significantly higher mean score (see Table 2). Once again, the effect size was small (partial Eta squared = .031).

Although only the Logical Sentences test indicated significant differences between control and experimental groups, our qualitative analysis yielded more promising results for the experimental group.

Teachers reported that they observed that game development activities positively affected student learning in several ways. These positive outcomes included increasing content retention, promoting higher engagement in activities related to comparing and contrasting information presented, encouraging students to utilize more and different kinds of research materials, enhancing editing skills, and providing an insight into questioning skills.

According to teachers, the extensive question creation activities, which were fundamental to the game creation exercise, required students to examine the materials in a thorough and critical manner. The thoroughness with which the students reviewed the material in order to develop questions for the game resulted in a higher level of integration and personalization of the unit material. One teacher commented that he felt that his students' grasp of material was likely improved as a result of the game development activities, and that "they'll be able to retain this. I guess that's what I'm looking for. Retention of this unit." No gender differences in learning outcomes were reported by teachers; however teachers did report that boys enjoyed playing their games more competitively against each other.

The question creation activities encouraged the students to reflect on the unit content and to repurpose the material into a format that could be incorporated into the game shell. These activities required students to compare and contrast information. For example, one of the questions entered by a pair of students was "How many provinces use Aboriginal languages?" (answer: 3). This illustrates the students' ability to take information about the single province that they were studying, and compare it to provinces that their classmates were studying, in order to arrive at the correct answer for the question they were creating.

As a consequence of their need for a variety of material to build multiple questions, students utilized research material from many different sources. For example, information was acquired from maps, video, and Internet sources to supplement the text and library books traditionally used to support the social sciences curriculum. One teacher noted that:

> The kids were coming in asking for research materials and charts and this and that to get their questions from. They were really into that. I had a couple of my own pieces of research material that they came and asked for consistently when they were making their questions.

Students were motivated to carefully formulate the questions, using correct spelling and grammar, because they realized that their classmates would eventually play the games they were creating. They not only checked and edited their own questions, they often pointed out mistakes to their classmates when playing the games. Additionally, editing and careful construction of the questions became meaningful activities for the students because there was a tangible outcome—the game—and an authentic audience—their classmates. As one teacher stated:

> It was a good lesson for them in their writing. Reflecting on their own writing and others' writing. It was a lot different from when they write a story, revise and edit it, and they say everything is fine and they don't make the changes. But with this game you really questioned the question. Did it make sense? Obviously, you know... there's a real purpose in editing it so that it makes sense.

Grade 4 students typically are not taught to create questions, and none of the students involved in this study had received formal instruction on strategies for creating any questions, let alone higher-order thinking questions, prior to the start of the project. The project gave students extensive practice in developing meaningful questions, and by the end of the study most students exhibited much higher skill in this task. One teacher described the effect that game development activities had on her students this way:

Table 2
Student writing test subtest scores: descriptive statistics by student group.

Student writing test subtest	Group	Mean	Standard deviation	*N*
Vocabulary	C	13.47	2.972	128
	E	14.22	2.581	178
Sentence Combining	C	10.41	4.409	128
	E	10.27	4.640	178
Logical Sentences	C	11.39	3.967	128
	E	12.70	3.162	178

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There is certainly big, big value in teaching kids how to develop questions that demand more. Because that is what we're doing, we're developing questions as their knowledge base increases and they get a bigger global idea of how it all works, but then to be able to put together questions that are demanding more out of someone that they are speaking to, is a good skill to have.

Students appeared to enhance their writing skills and knowledge of the subject as they played each others' games, particularly if the teacher allowed the class to review games together as a whole or in teams as many did. One teacher noted that:

We played one [game] together, at least one as a class, that way we learned more from it because we talked about the question and what we thought the answer was, and then if they got the answer wrong we could talk about what the right answer was.

This strategy helped students to improve their literacy skills, by discussing and editing questions, and also improve their knowledge of the subject, by reviewing and discussing content related issues as a class.

In summary, we found significant differences between the control and game developing groups on only one of the standardized test subscales, Logical Sentences, on which the game developing students scored higher. Teacher reports, however, suggest that students did improve basic academic and literacy skills from game development activities including content retention, comparing and contrasting information presented, utilizing a variety of research materials, editing, and higher level question creation.

3.2. Development of digital literacy skills

Our second research question asked what new digital literacy skills students developed as a consequence of game development and play. As no standard measures were available to assess this kind of learning we relied on our field notes and teacher interview data for evidentiary support.

Teachers noted that students enthusiastically shared their computer expertise and actively helped each other resolve technical issues by offering suggestions and encouragement when difficulties arose. One of the technical issues which interfered with the students' ability to engage in game development activities was the problem of pop-up blockers appearing on the screen, which stopped the game development environment from functioning. Students worked collaboratively to troubleshoot and resolve this problem at several schools. One teacher noted that "they had trouble with the popup at first. And then the kids figured out what was going on." Although some teachers were not comfortable allowing students to assume responsibility for this kind of technical support, others expressed some admiration and appreciation for the level of computer skills exhibited by their students.

Students also increased their knowledge of the game shell software itself, as they were expected to master skills such as editing or changing display settings. Some students explored the software application to learn these skills through trial and error, while others requested help from the teacher on less intuitive aspects of the software, such as using the "Modify" button which allows users to go back and alter the contents of a completed game. By the end of the study many students demonstrated great comfort with the game environment, and were using the more sophisticated aspects of the software, such as previewing their game questions, to track their progress.

Students also became comfortable using a variety of forms of learning materials. In their eagerness to create interesting and more complex questions, they spontaneously asked teachers for access to and utilized media such as maps, videotapes, and online resources. We observed students using, among other online resources, Wikipedia to research game questions, and noted that some of the students were very Internet literate. They found the Internet to be an efficient tool to conduct their research. For example, when we asked one student why she was using the Internet to research her questions, she responded "I would rather use the Internet. It has way more information."

The online nature of the game environment and the public access to the games created using the shells opened a possibility of educating the students in the study about the public nature of the Internet. Throughout the study several students demonstrated low levels of understanding that the games that they were creating were accessible not only to their classmates, but to students in other schools, and the wider audience of the game shell users. As a result, some questions were poorly formulated for an audience beyond their classroom walls (e.g., Where is my desk in the classroom?). However, we observed students accessing games created by the users in the larger *Education Games Central* gaming community and enjoying that aspect of the game environment. Thus, although this aspect of digital literacies was not an explicit focus of instruction, online environments like the one in the present study can be used as vehicles for teaching students about the public nature of the Internet.

Teachers of students with immigrant and minority background reported that these students interacted in the game development activities equally effectively as their peers. Students were allowed to create their questions at home, allowing English language learners the time to review and organize their questions without taking away from their class time. Once the questions were formulated, the students actively engaged with their classmates in the editing and refining of the questions by both providing input for their classmates and receiving suggestions about their own questions.

In order to make the game development activities even more meaningful, some of the teachers proposed that the games be used to provide input for assessment on the social studies unit. Students were motivated by game development in and of itself; however teachers felt that students may value the activity to a higher degree if marks were assigned to the games and/or the questions that the students created. Teachers themselves felt pressure because they "had to do something else in literacy to assess them," as one teacher said, so integrating evaluation into the game development activities may offer some benefit to teachers.

Another suggestion from teachers was to use the games as a review activity. One teacher said that playing the student developed games "would be a good summative activity for a unit" and that "being able to pull questions out" of the game for this purpose would be valuable.

Finally, teachers proffered that it would be beneficial to have a pool of games available which were developed by teachers, in subjects across the entire curriculum, so that students might play the games as a review activity, prior to assessment, or as a culminating activity.

3.3. Student engagement

The third research question concerned the impact of student game development on engagement. Our findings were very positive in this regard. Indeed, teachers reported that the game development activities of the study engaged students in the *Tracks Across Canada* unit

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much more than they would have if they had used traditional teaching methods. Some students were so excited by the game development activities that they continued to develop games on their own outside of class time, either by creating games related to their hobbies and interests or engaging in game playing activities with friends and family. Once when we entered a classroom we found students very excited as one team was showing off a game they created at home about the local baseball team. Moreover, at the conclusion of the study we found at the game website many games asking trivia questions around topics such as sports teams and television shows.

Teachers reported that often students had to be re-directed from playing both their personal and the curriculum unit games at inappropriate times during the school day, thus providing further evidence that the students found the game playing activities interesting and engaging. Teachers felt that part of the reason for the high levels of motivation seen in most of the classrooms was because students could access each other's work so readily in the game shell. Having an audience play the games they developed and being able to play those created by their classmates added to students' motivation and their desire to finish the task. One teacher remarked that the students "wanted to play each other, their friends, try to get (the questions) right and beat them. It was very engaging." Another teacher felt that student motivation was enhanced by the quantity and type of resource materials that they had available. "My students were really engaged when they had good age-appropriate materials, they were really excited about it, and they liked talking about it." Some students wanted to continue to construct games related to subjects outside of the *Tracks Across Canada* unit and approached their teachers with ideas for this. For example, one teacher reported that "The kids said 'Can we do math questions? You know, 14 times 7'. They wanted to be able to pull all their subjects into it (the game shell)."

The project implementation plan called for game development to be interspersed throughout the unit at the end of each major section. Teachers on the whole found this strategy effective as it motivated students to persist with the non-game work in the unit. Said one teacher "... actually the break was really good with them. They were much more intense with the next game. They enjoyed it a lot more." Initially, however, some teachers expressed concern that the students would no longer be motivated during these periods of non-game work, but the promise of game work at the end of the unit section served to keep students on task.

Teachers welcomed the high level of engagement afforded by the games work because the required curriculum unit, Regions of Canada, is considered by most teachers to be quite "dry" and difficult to complete. The game development activities motivated students to not only complete the work, but to engage in extensive research, organization, and collaborative activities with the materials presented. When discussing her students' persistence working with the game shell, one teacher noted that "my kids never really lost interest—they were always glad (to work on the unit)".

Our classroom observation suggested that the optimum amount of time to spend at a sitting on game development activities was about 45 min. After that students would tend to go off task and no longer be as productive. When following this daily schedule students remained engaged with the game activities for many weeks before they began to lose interest.

3.4. Teacher classroom practices

The game development environment and the *Tracks Across Canada* unit we used in this study were entirely new to teachers, although they were familiar with the topic of the unit itself as it is part of the regular grade 4 curriculum they are required to teach. They acknowledged the difficulties of using a new materials and media for the first time, and felt, as one teacher expressed, that "next year, I know more on how to guide them (the students), where I need more questions, and what type of questions to talk about."

One teacher extracted the essential content and strategies of the curriculum unit, wrote it up, and shared the document with other teachers. Many of them chose to adopt this simplified form of the unit. As the teachers taught the unit and utilized game development and question creation activities, they modified their pedagogical approaches and techniques when they encountered content they had not taught before. One teacher noted that "to me, this was all learning. I was learning, they (the students) were learning." As a result of this exercise, the teachers offered advice about how they might be best supported when integrating game development into their teaching and curriculum, and what approaches could be most effective. Several suggestions for utilizing game development activities in elementary classes from the teachers involved in the study follow.

When introducing students to the skills involved in writing questions, teachers suggested a strategy which worked well was to model the type of higher-order thinking questions for the class, and to have them discuss various questions to analyze their suitability for the game. In order to do this, one teacher created a form for the students to fill out to help them organize the structure of the questions. She then asked the students to exchange the forms and provide feedback to each other on the questions, thus encouraging critical analysis of question creation and enabling each student to receive immediate feedback on their work.

In all of the classrooms, teachers created teams of two or three students which were to work collaboratively to develop their games. They assigned students to groups based on many criteria: mixing levels of computer and typing skill; mixing high and lower academic achievers; or putting students together who seemed to be personally compatible. One teacher reported putting boys and girls together, while the majority of teachers opted to pair students of the same sex together. A few teachers elected to create teams of three students working together when one of the students in the team was not expected to contribute consistently to the team effort.

On the whole the team approach worked well. Typically teams would discuss their questions before entering them into the game shell, oftentimes debating the merits of a question first. Teachers reported that students with stronger academic abilities spontaneously helped students who were experiencing difficulties, an occurrence supported by our classroom observations. According to one teacher "the more gifted students would create some inferencing (questions) and if they were with another student in my class, they would kind of help guide them."

Several teachers encouraged individual teams to work with other teams in their class. Teams engaged in activities such as correcting each other's spelling mistakes and checking the accuracy of factual information while playing the games. Said one teacher: "They'd be playing the game, they would tell that person (about an error), and that person would get the peer pressure to get it correct, which was great." Another teacher added that:

> Students' strategies also included learning from their classmates. And they did share their questions with their friends. So that they were able to pick up other questions and re-word them, you know, if you like that style of question, take that and reword it and make it your own.

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This cooperative learning appeared to help students critically examine questions, evaluate the style and content of questions, and then improve upon them and incorporate them into their own game shell. Students also monitored their own progress in the game development activities by comparing their game to those of others. A competitive element sometimes manifested itself around game building: as one teacher noted "kids ask each other about how many questions they have done in order to compare their own work to their classmates."

The game shells offered the students the opportunity to create different types of questions. Teachers noted that some question types, for example, true or false questions, were easier for students to create, whereas more difficult or complex question structures such as multiple choice questions, required more rigorous question development efforts. One of the suggestions from teachers was that this type of higher level question be introduced only after students master construction of lower level factual recall question types. Describing her experience watching students develop questions, one teacher said:

> I found the game with the multiple choice questions was a lot more effective. Their questions were a lot more thoughtful when they had to give three answers. They found it a lot more challenging to do a thoughtful yes or no question because they have this fact, this really obvious fact, about their province or region or whatever, and they can't think of a way to make it a difficult true or false question.

As noted earlier, the optimum amount of time that grade 4 students remained engaged in a single sitting was approximately 45 min. Teachers suggested that interspersing computer-based activities, such as setting up the game, entering questions, and playing the game, should be alternated with other activities such as reviewing research material, writing the questions, and engaging in editing and review activities. One teacher described this as "breaking (it) up into each lesson." Teachers saw this mix of on and off of the computer activities as a way to prolong and enhance the motivation of students.

Teachers suggested that having students create small numbers of questions as they worked through the resource material avoided a feeling of being overwhelmed by the task. Instead of asking students to sit down and create 20 questions in one period, they recommended that students be responsible for creating two or three questions each day over a longer period. Teachers felt that they "want a space in it, honestly", because game development was an intense and challenging activity for grade 4 students.

Teachers also proposed that getting students to improve their previous questions by rewriting them as higher level questions was a very effective strategy, both to improve literacy skills, and to improve students' ability to edit their own work. One teacher described her strategy, and its outcome, this way:

> So I would tell them to pick out the questions that you think you wrote well, use those, add questions with the new information that we've learned from the last section of the unit, and then if there are some questions, you still need questions, pick some of the old questions that aren't well written and re-write them so that they are better worded, so they are tougher questions, that kind of thing. And that seemed to work.

This strategy not only encouraged students to refine their previously created questions, but also to work to create new, high quality questions, that could then be taken and inserted into upcoming game shells.

Some teachers recommended using a smart board or projection equipment to display student-created games and involve the whole class in playing them. They found that this activity opened up dialogue, not only about the form of the questions, but also about curriculum content. As one teacher commented, "we learned a little more from it because we did talk about the question and what we thought the answer was, and then if they got it wrong we could talk about what the right answer was."

4. Discussion of results

Our goal in this study was to understand how teachers can use computer game development as a pedagogical activity to engage students in a broad range of literacy activities. More specifically, we wanted to know if students would improve traditional basic literacy skills, develop new digital literacy skills, and become sufficiently engaged in curriculum related game development, as well as to learn how teachers adopt and shape the practice of student game development in the classroom.

With regard to basic literacy skill development, no significant differences were found between control and experimental groups on any of the subscales of the GRADE test. The lack of any significant improvements could be a consequence of treatment limitations that arose during the implementation of the game development activities in the classroom, rather than the planned activities themselves being ineffectual in generating changes in literacy levels. As noted earlier, the number of games and questions created per class varied considerably which resulted in a lack of uniform treatment. This variation appeared to be due to the difficulty of teachers fitting the game activities into their teaching schedules as the demands on class time for our project were higher what would normally be allotted to the curriculum topic Regions of Canada. A major consequence of this was that, with a few exceptions and despite instructions to the contrary, teachers tended to focus on encouraging "efficient" student production of questions so as to generate the numbers of questions needed for completion of four games within the allotted time period. As a result, there was typically little effort made to model and coach students in the generation of high-inference questions (a time-consuming process), and consequently a large majority of the games students developed incorporated only low-level factual recognition or recall questions. Extant research suggests that teacher modeling and coaching for higher-order thinking is a highly desirable strategy for promoting reading and writing fluency (Block, Gambrell, & Pressley, 2002; Booth, 2001; Taylor, Pearson, Peterson, & Rodriguez, 2003), thus the lack of significance on the GRADE subtest scores was perhaps not too surprising.

Although the GRADE yielded non-significant differences, we found significant differences favoring the experimental group on the SWT Logical Sentences test. This test required students to detect and correct illogicalities in sentence construction—a literacy skill called upon for game question generation. Game development required that students engage in the repeated construction and framing of Logical Sentences as questions; as a consequence, this particular literacy skill was, of those assessed in the three SWT subtests, the one most preferentially utilized in the game development group. Both student groups would have encountered the same vocabulary when the unit was taught, thus one might not expect much variation between groups in the Vocabulary subtest; and with respect to the Sentence Combining subtest, there is no *a priori* reason to assume that those in the experimental group would be engaging in more Sentence Combining in developing their game questions than control group students would in their activities. In developing their games, however, the experimental group students repeatedly engaged in the practice of reformulating factual information and concepts into new Logical Sentences—ones

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that took the form of questions. This process may have given them considerably more practice in detecting and correcting illogical sentence construction relative to the control group students, resulting in a higher mean score on the Logical Sentences subset.

The teachers' observations to the effect that students appeared to understand curriculum content better as a result of researching their game questions was encouraging. We did not specifically assess content retention, as our focus was on literacy skill development; however improved content retention is frequently cited as one of the major outcomes of game-based learning (Cordova & Lepper, 1996; Prensky, 2001; Squire & Barab, 2004). The reports from teachers that students tended to take greater care in composing and editing their questions because they knew that they would be read by their peers was also noteworthy. The notion of students taking care in producing more polished writing when they know that their work will be read by others is a long established principle upon which effective writing instruction is based (Calkins, 1991; Graves, 1983), and is cited as one of the reasons students tend to produce higher quality writing when using word processors as compared to writing by hand (Owston, Murphy, & Wideman, 1992).

Beyond providing students an opportunity to practice traditional literacy skills, our project clearly gave students extended opportunities to develop digital literacy skills, which was the topic of our second research question. The skills students either acquired or further developed included: using a new software tool (the game shell), accessing and browsing the web, understanding the public nature of web-based applications, mastering the processes involved in trouble shooting technical problems, utilizing the Internet for researching content, and using online maps. Skills such as these are seen as essential to include in contemporary curriculum because of the changing nature of what it means to be literate in today's society (Beavis, 2002). Because of the web-based nature of the game shell, students were able to work on their games from home which provided less able students with the opportunity to keep pace with their peers in class. This affordance also allowed students to connect their use of the Internet at home with their school work, and involve their parents in game play activities thus providing an authentic and interested audience for their games. Home–school connections such as this are is seen by many as crucial for literacy skill development as they provide parents with opportunities to become involved in their children's work and to understand the school's literacy program (Ontario Ministry of Education, 2004).

The third area we investigated was student engagement. As discussed earlier, the extant literature indicates that students are typically very engaged and motivated when playing commercial games in the classroom (Becta, 2001; McFarlane et al., 2002) and when developing games outside of the classroom (Robertson & Good, 2004). Our study found that game development—as opposed to game playing—can also captivate students' attention in a similar manner. Indeed, game development may prove to be more educationally effective for students than game playing because they can see the usefulness of what they are learning (i.e., learning content to develop game questions) and because they can use their learning to have an impact on others (i.e., others will play and learn from their games). Bransford, Brown, and Cocking (2000) stress that school activities that employ these design elements can be very highly motivating for students. Therefore, when game development is used in the classroom as a pedagogical activity it should provide for ample opportunities for students to play each other's games. Our findings also suggest that game development be targeted at curricular areas that teachers find challenging to motivate students. The topic Regions of Canada used in this study is one for which teachers in the past have had difficulty motivating students. However, by using the game development approach, none reported difficulty in capturing students' interest as long as the amount of time spent on the activity in one sitting was around 45 min, which was the normal length of most lessons at that grade level in the schools we studied. Even after spending this about of time once a week on average over a period of 10 weeks as done in this study, students were still very much engaged in their work.

Teacher classroom implementation strategies were the final area we investigated. We observed that all teachers followed our directions in using student teams to develop and enter game questions into the shell. On the whole this strategy proved to be successful and students appeared to benefit by improving their skills in working together in deciding the nature of questions to be entered, researching question content, fact checking, and editing each other's text. Beyond this, teachers varied their approach on how they implemented game development activities in their classrooms. The most notable differences were in how much time they devoted to helping students improve their question writing skills. All teachers taught a lesson on question creation as this was part of the curriculum unit, but the amount of reinforcement they gave students in improving this skill differed considerably. The majority provided almost no reinforcement and instead focused on the mechanics of game creation. A small minority modeled for students how to re-write knowledge recall questions as higher level thinking questions. A few projected game questions in front of the class and discussed with students how they could be improved.

The lack of pedagogical focus on question development strategies by most teachers appeared to be largely a consequence of the research design, which called for the development of four games in a 10 week curriculum unit. In retrospect, most teachers thought there was too little time allotted to the development of each game, and insufficient "gaps" between the different game creation activities. As a consequence teachers felt pressured to help students move as efficiently as possible through the development of the requisite number of questions to develop functional games. This "production" focus resulted in a lack of attention to students' development and refinement of higher-order questions on the part of most teachers, and thus led to students making question production a routine, lower-level activity. As discussed above, a consequence of this may have been the failure of the experimental group to demonstrate significantly higher scores on the GRADE test.

5. Summary and conclusions

This study examined the use of computer game development as a pedagogical activity to engage students in curriculum-related literacy activities. We investigated four main research questions dealing with student improvement of basic literacy skills, development of new digital literacy skills, student engagement, and teacher classroom implementation. As for basic literacy skills, we found students in the experimental group achieved significantly higher than the control group on only one of several measures—Logical Sentence construction. The new digital learning skills students developed as a result of the project included: learning to develop games using a game shell, accessing and browsing the web, understanding the public nature of web-based applications, trouble shooting technical problems, utilizing the Internet for researching curriculum-related content, and using online maps. We found that the game development activities engaged students over an extended period and motivated some to continue working on the game project at home and to develop additional games not related to the curriculum unit. Lastly, we observed that teachers implemented the game-based project successfully using heterogeneous

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groups of two or three students and found it a novel way to teach the topic, although most did not spend sufficient time or emphasis on teaching students how to develop higher level questions.

Overall, our findings led us to conclude that game development can be a viable option for schools that have the technology infrastructure to support web-based learning. It can serve to stimulate student interest and persistence in studying a curriculum topic that is intrinsically not particularly motivating for students, while at the same time promote modest improvements in literacy skills compared to traditional teaching methods. Even so, we believe that teachers will not want to use the activity more than a few times a year; otherwise, students will likely tire of creating the large number of questions required by all but the simplest *TicTacToe* game. Therefore, we recommend that teachers consider using the approach for topics in which they have had difficult engaging students.

While we contend that our study supports the use of game development as a feasible pedagogical activity, we also believe that more research is warranted to understand better how higher level questioning skills can be promoted as part of the game development process. If students produce more and better quality higher level questions, there will likely be greater impact on their literacy skill achievement. We believe that the most effective way to accomplish this would be to spread the teaching of the unit over a longer period, perhaps an entire school term, and provide teachers with greater guidance on writing and teaching high level questions.

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