

More than Just Fun and Games: Assessing the Value of Educational Video Games in the Classroom

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ABSTRACT

The objective of this preliminary study is to investigate whether educational video games can be integrated into a classroom with positive effects for the teacher and students. The challenges faced when introducing a video game into a classroom are twofold: overcoming the notion that a “toy” does not belong in the school and developing software that has real educational value while stimulating the learner. We conducted an initial pilot study with 39 second grade students using our mathematic drill software Skills Arena. Early data from the pilot suggests that not only do teachers and students enjoy using Skills Arena, students have exceeded our expectations by doing three times more math problems in 19 days than they would have using traditional worksheets. Based on this encouraging qualitative study, future work that focuses on quantitative benefits should likely uncover additional positive results.

Author Keywords

Handhelds, Gameboy, Education, Learner-Centered Design

ACM Classification Keywords

G.4 Mathematic software: General; K.3.1 [Computers in Education]: Computer uses in Education; K.8.0 [Personal Computing]: General -- games.

INTRODUCTION

Harnessing the educational power of games in the classroom is not a revolutionary idea; many teachers use games like crossword puzzles to teach spelling, “shopping” games to illustrate counting and arithmetic with coins, and so on. Previous research has shown that using video games into the classroom can be rewarding on many levels including academic achievement, motivation, and classroom dynamics [5]. There is, however, still resistance to the idea that educational video games can be useful tools in a classroom [2].

We have begun to investigate this issue by developing

Skills Arena, a mathematics video game that is designed to be easy for teachers to use in their classrooms, educational, and motivational for students. Skills Arena is designed to supplement traditional curricula and teaching methods while improving on conventional tools such as worksheets.

Before a quantitative scientific study can begin however, many questions on the viability of creating a video game for the classroom remain unanswered. Would teachers and principals be open to having “toys” in the classroom? Will video games improve the classroom environment? Can students benefit from playing a video game? Through the course of this initial pilot study, we have found the answers to these questions.

Research Approach: LCD and Scaffolding

Ongoing research in Learner-Centered Design (LCD) is developing new technology, curricula and professional development materials that integrate desktop and handheld computers into classrooms to support activities as diverse as story writing, scientific field experiments and online research. LCD recognizes that learners have unique needs – such as a lack of background knowledge and a lack of motivation – that need to be addressed in the design of educational software tools [4]. When using educational technology, learners’ needs arise both from the tool and from the activity. For example, in order to use a word processor to write a cover letter for a job application, learners must understand both how to create and edit a file using the word processor (a need arising from the tool) and what content and format is required in order to create a good cover letter (a need arising from the activity).

To address learners’ unique needs, LCD practitioners often incorporate additional supports or “scaffolds” into their educational software. Scaffolds are temporary supports that assist learners in engaging in an unfamiliar task [1]. In software, scaffolds often appear as part of the user interface, providing support and guidance throughout the activity. Skills Arena includes scaffolds to address learners’ needs when using computers to learn arithmetic.

DESIGN

Designing software for the classroom that allows each child to use their own device simultaneously permits few choices in hardware. Nintendo’s popular Gameboy Advance (GBA) handheld was chosen as the platform for Skills Arena because of its portability, price (approximately \$69 US

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Dollars), and ease of use. By using Gameboys we are tapping into a medium pertinent to our target audience and increasing student interest [3].

Skills Arena combines classic math drills of addition and subtraction with constant feedback, advanced scoring and record keeping, character creation, and variable difficulty levels. At the start of the game, new players create a character within Skills Arena by entering a name and selecting traits like skin color, eye color, hair style, and so on. Figure 1 illustrates the character creation screen. After creating their character, students select one of six ranked opponents – half give addition problems and the other half give subtraction problems. Opponents get progressively more difficult by increasing the speed at which problems pass by on the screen.



Figure 1: Character creation screen

After selecting an opponent, a match begins. Each match takes 2 minutes and consists of problems moving from left to right across the game screen. Players must answer the question correctly before it moves all the way to right and off the screen; otherwise no points are gained on that question. Once the player answers the problem, a new one appears immediately. A sample match screen is illustrated in Figure 2.



Figure 2: Match screen

After the 2-minute match concludes, a statistics page appears showing the number of questions answered correctly, incorrectly, and percentage correct, for the current match and of all matches thus far for that character. Table 1 demonstrates how design choices during a match

were made deliberately to create an enjoyable experience while meeting the needs of the learner.

Software features during play	Addresses student needs
A timer is displayed showing how much time in the match remains	Creates a sense of a goal and increases excitement
Character portraits (the player and opponent) are displayed	Students are motivated to see their character win
Players input answers by increasing digits in the ones, tens, and hundreds column by one with each button press	Supports current class curriculum of one, tens column math, and shows increases and decreases of numbers
Feedback is displayed in large font when a question is answered	Players receive instant feedback of their attempt
The Tool function is displayed in the right lower corner	Students can alter the question based on their grasp of mathematic concepts

Table 1: Software features that solve student needs

Scaffolds in Skills Arena

Skills Arena includes a number of scaffolds to assist learners in understanding and completing elementary mathematic drills. For instance, the ability to create a character onscreen provides students with a sense of “ownership” of their work, similar to adding their own names to a traditional paper worksheet. Other scaffolds are included to provide feedback on students’ performance and progress over time. For example, the statistics screen that is displayed after each match shows students how they did for the most recent match, and also displays the cumulative progress of the character for all matches. Other scaffolds must be created to supplement the new learning environment of the hardware and software; this need is addressed through an online instruction diagram, which provides scaffolding to help students understand how the hardware and software interact.

The Tools functions included in Skills Arena facilitate the acquisition of basic math concepts beyond what students acquire by memorizing addition or subtraction tables. These tools allow students to alter the current arithmetic problem in a variety of ways, allowing students more conceptual control over the questions. For example, students may see the problem $9+7$ (see Figure 2) and conceptualize the situation in many different ways. Students can alter the problem on the fly with a Tool function that adds one numerator or denominator to change the problem to $10+6$, which may be easier for some students to solve quickly. Or, students might use a different Tool to change the problem to $9-7$. The ability to manipulate arithmetic problems quickly using the Tools in Skills Arena allows students to investigate the underlying math concepts in a manner that is not readily available with more traditional worksheets and flashcards. Table 2 summarizes how the addition of characters, tools, rankings, and other scaffolds creates support for the learner, while Table 3 compares the functionality provided by Skills Arena against that offered by simple worksheet exercises.

Learner Need	Skills Arena Scaffold
Understand Gameboy controls and software instructions	Help menu showing diagram of the controller
Be motivated to complete math drills	Visual/audio rewards given on correct answers
Understand higher level math concepts	Concept of Tools introduced to allow revision of questions for greater understanding
Reflect on progress over time	Cumulative scoring and title rankings show improvements
Have ownership of their work	Character creation gives sense of ownership

Table 2: Learner Needs and Scaffolding Solutions

Needs of Students	Skills Arena	Worksheets
Fast feedback	Yes - the game provides instant feedback	Maybe - dependent on teacher
Appropriate difficulty	Yes - students can choose their difficulty	No - the whole class does same set of questions
Motivational	Yes - students choose to play Skills Arena even when not asked	No - students are not motivated to do worksheets without teachers asking

Table 3: Comparison of Skills Arena and Worksheets

CLASSROOM PILOT STUDY

We approached a local school with initial prototypes of Skills Arena and asked teachers if they would be interested in using the software in their classroom. The ten teachers we approached and demonstrated the software to all said they would like to be involved in the pilot study and the school principal supported the study as well. The initial prototype was altered based on teacher feedback, and we lowered the difficulty by eliminating double/triple column addition and subtraction and by slowing down the speed at which problems moved across the screen. The revised version of Skills Arena was piloted in two second grade classrooms (students approximately 7 years old) in a small Michigan city in December of 2003. We provided a set of 20 GBAs with cartridges of Skills Arena for the two teachers to share amongst their classes. 19 students (9 female, 10 male) in one class and 20 (10 female, 10 male) in the other participated in this trial.

Initial Observations

Students in both classes were initially excited about using Gameboys in the classroom. The first question we asked was “How many of you know what this device is?” when raising a GBA for them to see. In both classes, the vast majority of students both knew what it was, and almost as many had used one or seen one used. Two students in each class needed additional instruction about how to turn on the Gameboy, where specific buttons were located, and so on. These four students quickly picked up on the gameplay and physical manipulation – faster than the teachers and even the developers learned to use the GBA!

After our initial introduction of the software to the class, the teachers were free to incorporate Skills Arena into their

curriculum as they chose. One teacher used Skills Arena every morning, when the students first arrived, for 10 minutes before they started a math lesson. The other teacher did not make a schedule but instead used Skills Arena daily as part of a reward system for students who finished their assignments for the day on time; most students were able to play about 15 minutes a day in this class.

Data Collection and Results

Skills Arena was used for 19 days by both classes, and we collected data from the automatically generated log files twice. Test Period 1 consisted of the first 10 days of the study while Test Period 2 consisted of the last 9 days, and the log files were deleted after Test Period 1 so there is no overlap of data between the two test periods. The data gathered from the log files includes:

- Character name (usually the student’s name)
- Total number of questions attempted
- Total number correct and incorrect
- Cumulative percentage correct
- Minutes played and questions answered per minute

Table 4 summarizes the log file data from all students from each collection period. The 39 students in the study created a total of 153 characters. During the 19 day pilot study, each student answered an average of 1,296 questions and spent an average of 77.38 minutes using Skills Arena.

While the opportunity to create and customize characters within Skills Arena proved motivating to students, this did cause unexpected problems with data analysis. Most students created multiple characters with different names and occasionally forgot which characters belonged to them. Thus, it was not possible for us to reliably identify character ownership and so the results of this pilot study cannot be segmented by gender, classroom, or individual.

	Test period 1	Test period 2	Total for study
Total hours	22	28	50
Questions answered	17740	32786	50526
Problems per minute	13	19	17
Correct answers	12113	17786	29899
Incorrect answers	5626	15000	20626
Percentage correct	68%	54%	59%

Table 4: Summarized data from all students

Discussion

In reviewing the results of the pilot study, we discovered several interesting and surprising trends. The remainder of this section discusses these findings, including the impact of Skills Arena on the following areas:

- Students’ motivation and achievement
- Classroom culture and software adoption
- Spontaneous collaboration and creativity

Impact on Students' Motivation and Achievement

Perhaps the most surprising result from the pilot study of Skills Arena is that students completed an average of 1,296 problems each during the 19 days of the classroom trial. The worksheets typically used in these classrooms to conduct arithmetic drills contain 9-12 questions each and students may complete up to two worksheets per day. Thus, in a typical 19-day period the students in these classrooms would complete at most 456 questions. Using Skills Arena for the same period, these students completed nearly three times as many questions, on average, and were provided with instant feedback on their work rather than needing to wait for the teacher to grade and return their worksheets.

Another interesting finding from our pilot study was that, on average, students continued to increase the difficulty of the game (by increasing the speed at which questions travel across the screen) without direct instruction from teachers or researchers. While students completed 13 questions on average during Test Period 1, by the end of Test Period 2 students were averaging 19 questions per minute. This increase in difficulty was accompanied by a decrease in the percentage of questions answered correctly, however the total number of questions completed almost doubled in during the second testing period.

In order to further simplify the game for the students, who were only 7 years old, we decided not to discuss the Tools options in Skills Arena at all in the classroom. Surprisingly, we found that after just a few days using Skills Arena several students had discovered the Tools options and were not only employing them in their own matches, but were also showing other students how to use the Tools. By the end of study, most of the students were using the Tools regularly in patterns that enhanced their scores in the game. For instance, since the default answer to each question is zero and changing the answer requires pressing a button repeatedly to increase or decrease the result, students often used the Tools function to change a problem like $7+7$ into $7-7$ in order to be able to answer faster.

Impact on Classroom Culture and Software Adoption

In our pilot study, we found that a brief demonstration was all that was needed to explain the hardware and software to the students. Skills Arena had a dramatic impact on the classroom culture as well. Teachers reported that the activity was remarkably easy to administer and control because students were so well-behaved when using the Gameboys. Another surprising trend occurred in the classroom where Skills Arena was typically used as a reward for good classroom behavior (versus daily scheduled time). The teacher reported improvement in classroom dynamics and discipline, which is remarkable considering that the reward that inspired this good behavior was allowing students to do math drills!

Impact on Collaboration and Creativity

During the pilot study, we observed students helping others and interacting with their classmates while using Skills Arena. In one class, a student with special needs was

unable to manipulate the Gameboy quickly. Unprompted by the teacher or researchers, other students in the class devised their own solution to this problem: the student with special needs would watch the screen and give oral answers to a classmate, who would then input the answer on the Gameboy. The teacher reported that this activity was rewarding for all of the students involved and that it was quickly increasing the special needs student's sense of self efficacy in math.

Skills Arena also engaged students in more ways than just mathematic reasoning – students used their imagination to create stories about their experience. One male student was telling classmates that your opponent's head falls off when you reach 100%. We overheard other students discussing what happens when you create a character and give it the teacher's name (one female student was convinced the game automatically gave you 100% on all matches). While neither of these were true (nothing happened), the ability to create their own characters was clearly an engaging feature of this software.

CONCLUSIONS AND FUTURE WORK

This pilot study explores some of the issues involved with introducing educational video games into a classroom. We found that an entertainment computer can be used successfully in a classroom and that well-designed software can compliment, and possibly improve upon, traditional teaching tools. Based on feedback from this pilot study, we are further refining Skills Arena and are planning additional classroom studies to quantify whether using this software improves students' performance in arithmetic and to compare the impact of Skill Arena to traditional math drills conducted with worksheets and other exercises.

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REFERENCES

1. Bransford, J.L., Brown, A.L. and Cocking, R.R. (eds.). *How People Learn: Brain, Mind, Experience, and School*. National Academy Press, Washington, D.C., 2000.
2. Okan, Z. Edutainment: is learning at risk? *British Journal of Educational Technology*, 34 (3). 255-264.
3. Provenzo, E. *Video kids: making sense of Nintendo*. Harvard University Press, 1991.
4. Quintana, C., Krajcik, J. and Soloway, E. Issues and Approaches for Developing Learner-Centered Technology. *Advances in Computers*, 57. 271-321.
5. Rosas, R., Nussbaum, M., Cumsille, et al. Beyond Nintendo: design and assessment of educational video games for first and second grade students. *Computers & Education* (40). 71-94.