Enhancing Educational Tools through Conversion to Games

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PROBLEM AND MOTIVATION

Over the past two years we have performed middle school outreach with the Virtual Bead Loom (VBL), an educational tool designed to teach Cartesian coordinates, symmetry, geometry, and iteration [4]. We discovered that although the tool taught Cartesian coordinates and symmetry very well, few students were motivated to explore the harder concept of iteration [2]. To improve its teaching potential, we created BeadLoom Game (BLG) [2]. The BeadLoom Game is a puzzle game where players plot points, lines, rectangles, triangles, and iterative patterns onto Cartesian coordinate grids to recreate goals in the fewest moves possible. We hypothesized that integrating learning objectives into the game, as true game objectives, would increase student motivation and learning gains. Since pre and post test questions can be viewed as objectives, it makes sense to convert these learning objectives into in-game objectives. In many educational games, game play and learning are separate, unrelated, or weakly related elements. By incorporating learning into the core game mechanic, the main activity of the player, we allow for incremental improvement and learning through play and this can directly translate to post test improvement.

Through our first controlled study we found that BLG teaches Cartesian coordinates, iteration, and the additional concept of the painter's algorithm. Players also found BLG more fun and engaging than the VBL [2]. In our summer 2010 controlled study, we found that BLG better motivated students to use advanced features, taught the concept of Cartesian coordinates equally well, and resulted in higher learning gains in iteration and the painter's algorithm when compared with the VBL [3]. During this experiment we also observed that students could be grouped into two categories: competitive or creative.

The competitive students often grouped together and would brag about and compare scores with one another. These students would often play and replay the same puzzle multiple times to improve their scores and times to out-do their friends. To take advantage of this phenomenon, we added a high score board to each puzzle that ranks players based on performance. This allows for comparative feedback and very strong motivation for the competitive students, which leads to re-exposure and mastery.

Some of the students who self described themselves as creative reported preferring the original Virtual Bead Loom. They explained that they either liked the creative freedom it allowed or that they did not like the pressure of competing for a better move count and time. To accommodate these players we added in a Custom Puzzle mode, where players can create their own designs and submit them for other players to rank and play in the game.

We found that the addition of these new game mechanics further augmented the game and resulted in higher motivation to play and replay the game. By adding game elements to an already successful educational tool we were able to increase student motivation to explore the full features of the tool and increase student learning gains. This has led us to ask: Which game mechanics are most responsible for the success of the BeadLoom Game, and can a simple method be developed to augment successful educational tools into more motivating and successful educational games through the addition of specific game mechanics?

BACKGROUND AND RELATED WORK

Games have great educational potential because of their inherent motivational properties [1,5]. This internal motivation is very important because it engages students in education outside the classroom [6,5]. Students are driven to replay fun educational games and this replayability is an important component of their success [10]. Yet there is currently limited information on the correct way to design such educational games to maximize the educational content and replayability for the greatest number of students [8, 9].

Some successful educational tools and constructivist learning environments rely on external motivation, and do not provide targeted challenges for learners. A good challenge, with a balance between ease and difficulty, is very important for educational games [7]. We hypothesize that by augmenting existing educational tools with game mechanics and converting them into educational games we can introduce this challenge and provide internal motivation for exposure to and mastery of the learning objectives. Game mechanics can be defined as "the methods invoked by agents for interacting with the game world" [11] or the various ways players interact with all the parts of the game. However in order to do this we must determine what game mechanics are required for the conversion of successful educational software into more motivating and successful educational games. These essential mechanics, if such universal ones exist, can then be viewed as the cornerstones in the design of educational games.

APPROACH AND UNIQUENESS

In order to develop a system for converting educational tools into educational games and identifying the key game mechanics for successful educational games, we must first analyze the success of BLG and determine which mechanics contribute to its success. The BeadLoom Game currently incorporates three main game mechanics: embedded learning objectives, competitive leader boards, and creative user generated custom puzzles. We developed these mechanics so that we can selectively turn them off or on. In this way, we can tailor BLG to expose experimental groups to particular game features and compare the learning gains and preferences across groups. Unlike other educational game based studies that only seek to identify if a game is successful our goal is to identify why our proven successful game is successful. By doing so we can identify the mechanics that need to be in all educational games to maximize enjoyment and learning gains across the widest range of students.

In order to evaluate the different mechanics we used three different measures. The first compares the learning gains using a simple pre to post test using the original Virtual Bead Loom (VBL) tool as a control. Secondly we used in game logging to monitor which game mechanics were being played the most by each player to determine which were the most popular. Finally we used simple surveys which asked the participants which mechanics were their favorites and which ones were their least favorite and to explain why in their own words.

Our study was conducted with six middle school technology classes. These classes were all exposed to all the versions of the game but in different orders in order to avoid students simply reporting liking the most recent game mechanic. Group A was first introduced to the original Virtual Bead Loom for use as a baseline measurement. Next they worked with the basic BeadLoom Game with neither the leader boards or user generated content (in other words, the VBL with embedded learning objectives). After that they worked with the BeadLoom Game with the custom puzzle game mechanic and finally they were given the full game with leader boards and custom puzzles. Group B followed a similar pattern but with leader boards introduced rather than the custom puzzles before being given the full version of the game. Each session students were given a survey and test and were then introduced to the new game mechanics. They were then allowed to play with any game mechanic they wanted for the session as well as at home in between class sessions. By following this experimental design we were able to acquire an accurate baseline from the original Virtual Bead Loom tool. We were also able to fairly allow all students to have access to each game mechanic and survey their opinions on each one. Most interestingly we were able to see how having access to some and all of the mechanics changed their opinion of the game as a whole. For example we were able to analyze how having access to only the competitive high score boards compared to having access to both the high score boards and user generated content. This is different from traditional games research which only looks at the game as a whole and may not account for features that may have strong polarizing effects such as competitive ones.

RESULTS AND CONTRIBUTIONS

The results of this experiment confirmed our earlier results, showing that the original BeadLoom Game outperformed the Virtual Bead Loom. This shows the effectiveness of embedded learning objectives as game objectives. The next most successful was the BLG with either leader boards or custom puzzles. The version with the highest gains for both groups was the full version of the game with both custom puzzles and leader boards. Figure 1 shows the test results for both groups. Due to scheduling complications B day followed a slightly abbreviated schedule (Pre: No treatment, Mid3: leader board treatment, Post: full game) while A day followed the complete schedule (Pre: No Treatment, Mid1: VBL, Mid2: Original BLG, Mid3: custom puzzle, Post: full game). As the figures show the sharpest increases occurred when given the full version of the game.

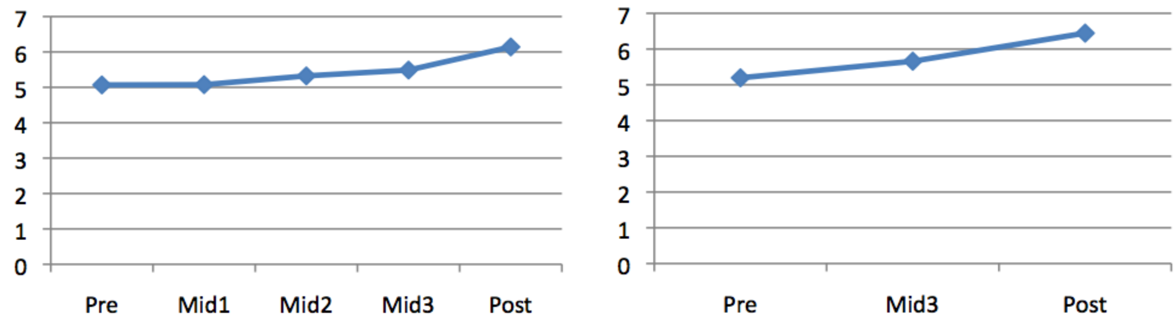

Figure 1: A-day Test Scores (Left) and B-day Test Scores (Right)

A paired t-test was performed on the data from both groups. The mean grade on the post test (M=6.12, SD = 1.98, N=51) of the A-day students that completed both the pre and post test was significantly greater than the pre test scores, t(50)=2.34, two-tail p = .02. A 95% C.I. about average score increase is (.09,1.2). Similarly the mean grade on the post test (M = 6.48, SD=1.79, N=60) of the B-day students that completed both the pre and post test was significantly greater than the pre test scores t(59)=5.68, two tailed p < .001. A 95% C.I. about average score increase is (.85,1.77).

According to the surveys taken during the same times as the tests we also had a large increase in players who preferred the BeadLoom Game over the Virtual BeadLoom. From the first survey to the last the A-day group went from 71% preferring the BLG to 85% with the addition of the competitive leader boards and creative user generated content. Similarly the B-day group began with 76% preferring the BLG and rose to 88% preferring the BLG. This shows the importance that these features have in altering players preference of a basic tool versus a game.

More interestingly than overall preference changes is what happened between the Mid3 survey (either user generated or leader boards) and the Post survey (both mechanics). If we look at player preferences by gender (Table 1) at Mid3 we notice an interesting difference between the two groups. While the Male players are relatively similar (especially if we combine the two versions of BLG together) there is a big difference in female preference between groups. While only 7.7% the women in the A-day group (which had user generated content at this point) preferred VBL, 37.5% of women in the B-day group (which had competitive highscore tables) preferred VBL. We believe that the competitive elements of this version of the BLG were highly polarizing for this group and that the complete lack of creative free play modes turned off some players. However, this effect did not occur in the male players. This gender difference also went away by the Post Survey (Table 2) when both groups' version of BeadLoom Game had the Custom Puzzle content. This suggests creative free play and non-competitive elements are especially important to include for motivating middle school girls.

Table 1: Preference By Gender at Mid3 (%)

	A-VBL	A-BLG	A-Custom	B-VBL	B-BLG	B-Comp
Male	17.4	4.3	78.3	11.4	14.3	74.3
Female	**7.7**	23.1	69.2	**37.5**	6.3	56.7

Table 2: Preference By Gender at Post (%)

	A-VBL	A-BLG	A-Full	B-VBL	B-BLG	B-Full
Male	20	10	70	9.1	9.1	81.8
Female	11.1	7.4	81.5	15.4	7.7	76.9

By looking at the play logs of the students we were also able to determine some effects the different game mechanics had on play time. As a general trend, play time went up as we introduced additional features. Although a game with more features being played more than a game with less features is not of major note, one important trend did occur between the addition of the competitive and user generated mechanics. If a student reported in the surveys that they did not enjoy one feature (creative or competitive), when the other feature was added we noted a very sharp increase in play time. This shows that a game that has game mechanics that only cater to one of these areas may have lower overall play time than a game that contains both and thus caters to both types of players. We also continued to monitor play time after the end of the last session. Over the student's winter break while they were at home on vacation we continued to log active play and new custom puzzles being created. During this winter break the students played the main game of solving puzzles for over 23 hours and published 65 new custom puzzles. The students were playing and thus learning on their own for primarily entertainment purposes during their vacation from school. This is the ultimate goal of any educational game and these three game mechanics directly contributed to it.

Beyond the formal analysis we saw two interesting phenomena occur with the new features. One concern we had with the Custom puzzle mode was that it may suffer from the same issue as the original Virtual Bead Loom in that if there is no motivation to use the advanced functions like iteration, the player may only use simple ones like points and lines. However, the social nature of the custom puzzle rankings seemed to prevent this. Since puzzles were displayed in order of user rankings, if players wanted their art to be seen and appreciated they had to make them complex and appealing to all players. This generally resulted in players creating complex artwork with a great deal of iteration and layering as Figure 2 illustrates. While this motivation stemming from the player base rather than the game is similar to the competitive motivation of the leader board, this motivation generally appealed to the creative students with many of them reporting that they "liked having other people see and rate their designs." This fed into the second observation which was a form of content loop. A problem with any game is that once you beat it, it is over. For educational games this means that the learning ends. However through the combination of the user generated content and leader boards the BeadLoom Game is able to avoid this. There are always new puzzles to solve and always new high scores to beat. In addition, the creative players continue to generate more and more challenging puzzles which pushes the completive players. In turn the competitive players leave comments for the most skilled creative players asking them to create even more complex puzzles. Each group provides motivation for the other pushing both groups to higher mastery of the learning objective. This is a powerful loop that we hope can be incorporated into all educational games to maximize learning gains and replayability.

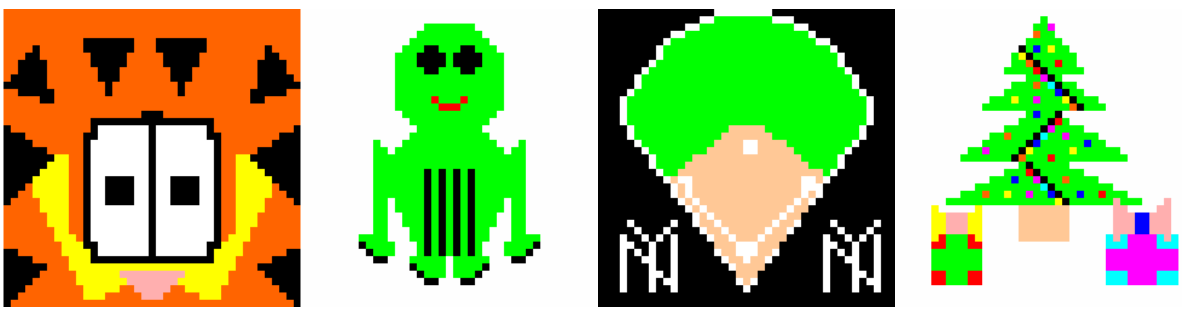

Figure 2: Custom Puzzle Examples

We have successfully identified the elements required to convert the Virtual Bead Loom, a successful educational tool, into an even more successful educational game. We believe these game mechanics are also the cornerstone of making successful educational games that appeal to and are successful for the largest possible group of students. The integrated learning objectives ensure all game play contributes to learning, while the competitive leader boards and creative user generated content maximizes motivation for two very differing groups of players. We believe that these types of mechanics need to be integrated into all educational games to maximize their educational and entertainment value. While we acknowledge that integrating learning objectives into games may not always be so straightforward as it was for the BLG, we believe that our results show how important this is. Making elements that appeal to both creative and competitive students are also key – and when these two can complement each other as with the BLG, this can contribute to a golden loop of replayable educational content. We believe that our results will help establish a framework for educational game design, where before there was no such framework available.

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