Article

Using Game-Based Learning to Improve Learning Outcomes in K-12 Mathematics Education

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Keywords: GBL; Games; Education; Learning; Motivation; Mathematics; Gamification

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Using Game-Based Learning to Improve Learning Outcomes in K-12 Mathematics Education

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Abstract: In this paper I describe elements of Game-Based Learning that can be used to support mathematics teaching using games. After creating a game that incorporates the elements described, the game was playtested against a small number of people who answered a questionnaire focusing on user experience, learning motivation and game design. The results are attached separately as well as the analysis. I believe that with further development this game-based approach can be a powerful tool to gamify common learning tools and increase learning motivation and appreciation.

Keywords: GBL; games; education; learning; motivation; mathematics; gamification

1. Introduction

Game-based learning (GBL) is the use of video games to support teaching and learning (Perrotta et al., 2013.) Now more than ever, mathematical skills play a growing role in our lives, as the foundation of much of computer science and data science and indeed a lot of the modern technology that drives much of our lifestyle. Despite this, a large number of students look at mathematics in a negative light. Games are a ubiquitous part of human culture, and there is no doubt that they have a great potential for educational purposes. In recent years, video games have grown to over $100 billion a year industry (Vilches, 2011) and have become the preferred entertainment method for a lot of individuals, due to their accessibility through multiple platforms and catering to all tastes and experience.

Games also have the ability to motivate the players intrinsically (Kebritchi, Hirumi, 2010), and it is no surprise that educators are trying to use them to improve instruction.

The video game industry has been growing at an accelerated pace for many years and for some has become an important part of modern culture. One of the advantages of GBL is in its intrinsic entertainment value, as the main function of a game is to entertain and teach (Annetta, Minogue, Holmes, & Cheng, 2009; Hays, 2005; Lee & Peng, 2006; Lieberman, 2006; Moreno & Mayer, 2007; Rieber, 2005; Tobias & Fletcher, 2007; Tobias & Fletcher, 2008.) It is not surprising that the application of video games to the education field has been explored. In fact, some believe that there are inherent benefits to using video-games for learning (Gee, 2007). There are several ways to borrow successful techniques from game-design and incorporate them into the learning context. Focusing on the game-design techniques that are most suitable for learning will result in a measurable increase in short term mathematical performance, as defined by accuracy in a time-based assessment, and in increases in intrinsic motivation, perhaps an even more valuable metric (Mayer, 2014). This is because motivated learners are more likely to make the effort needed to understand what is being taught as well as how it can be applied into their own lives (Omrod, 2014.) There is a growing body of work in the area of game-based learning, focusing on different aspects such as meta-cognitive strategies (Kim et al., 2009,) the effects on attitudes towards mathematics (Çankaya & Karamete, 2009) or the psychology of learning mathematics (Sedighian et al,. 1996.) There was also a large body of work focusing on motivation and achievement (Mansureh Kebritchi et al., 2010) or motivation in areas different than mathematics (Tüzün et al., 2009.) There has also been a good amount of research on some of the feedback mechanisms I am interested in, such as achievements (Tsai et al., 2016,) badges (Alaswad, 2015) and contextualized learning (Hwang et al., 2015.)

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Finally, there is also analysis on GBL focused on mathematics education (Byun & Joung, 2018) as well a number of literature reviews (Hussein et al., 2021) and (Pan et al., 2022.) Most Studies focus on why a certain aspect of game-based learning works or doesn't work in their study group, but few if any consolidate the most effective techniques, particularly in one domain of GBL and education.

It stands as no surprise that games can be used to teach and are being used for educational purposes. Every game at a minimum teaches you how to play itself, so there is an implicit understanding of learning whenever we play a game for the first time. It is the hope that the love for video games of the younger generations can be leveraged in games that have some educational benefit and can potentially be used to improve learning outcomes.

2. Materials and Methods

2.1. Advantages and Disadvantages of GBL

GBL is a form of learning that uses games and simulations to help students learn. The idea in general is that learners will approach learning more actively when the topic is presented in the form of a game where the learner can enjoy the process of learning and actively engage with the material in a fun and interactive way. However it is not clear whether using games in learning has a demonstrable positive impact on cognitive gains for the learners. In fact, in 2006 Vogel et. al published a study which concluded that students who were engaged in playing video games and interactive simulations did have better cognitive performance and better results on motivation than students that spent their time studying traditional textbooks. However the results of this study have been called into question by other research that has looked at the effects of different types of game play and the factors affecting their effectiveness.

The notion is that effective learning games do both; they engage the player cognitively and they boost his intrinsic motivation which feeds into the learning cycle. Some of the methods that have been shown to be effective include enhanced interactivity, adaptive challenges and ongoing feedback (Rupp et al., 2010; Shute, 2008.)

On the flip side, games in education can sometimes focus too much on entertainment at the expense of learning. In fact, if the design of the game is not deliberate, non educational aspects of gameplay can cannibalize the players attention and detract from the educational value (Gee, 2003).

2.2. Alternatives to GBL

Game-based learning is not the only option for interactive educational experiences. Gamification is another option that is gaining popularity in schools and companies. In gamification, game mechanics are applied to non-game situations in order to improve user engagement and motivation (Hamari, 2007). Unlike game-based learning, there is no explicit connection between the learning experience and a game. However, some elements of gamification are the same as those used for game design. For example, game mechanics such as reward systems, leaderboards and challenges are a great way to increase engagement and encourage people to continue playing.

Both approaches have their own strengths and weaknesses and should be assessed on an individual basis to determine the type of experience best suited to the needs of the individual learner.

Serious games are games in which education is the main goal and not entertainment (Ahmed & Sutton, 2017). There are serious games that simulate real life situations or teach real-world skills. Examples include medical training simulations that teach students how to perform medical procedures safely, firefighter training simulators that teach them how to operate in dangerous situations, and air traffic controller training simulators that provide training in airport procedures.

Finally Simulations attempt to imitate reality, recreating it for the user to experience (Cai, Goei & Trooster, 2016). They are in some ways an enhancement of serious games and in another a focus of their scope. They can be entertaining but recreating the original experience is their focus. Typically they are used for training and for enabling experiences that might be hard inaccessible at any given time. (Ahmed, Sutton, 2017.)

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2.3. Principles, Characteristics and Mechanisms of GBL

There are several game design elements that are well suited for educational games, such as player collaboration, player-generated content, feedback and replayability. Being able to tailor the difficulty level to the player is a hallmark of modern game design and it is exactly between too much challenge and too little challenge that the learner can achieve balance, when it is equal to his skills. This is what is called a state of flow (Csikszentmihalyi, 1990) and it is described as a state of constant engagement and optimal experience. Clearly achieving this state would be favorable to the player and so it is important that we start with clarity in design and goals, and that feedback is provided to the player so that they can improve and overcome the particular challenge (Bateman & Boon, 2006.)

There are 5 principles to GBL, which are: Intrinsic Motivation, Learning through Fun, Authenticity, Independent Play and Learning by doing (Perrotta et al., 2013). Intrinsic motivation is one area where most of the research agrees has the potential to reflect positive gains. Simply speaking the game motivates the player through its systems and the player in turn is driven to continue playing (and learning) perhaps without explicit learning objectives. Furthermore, the gains in motivation can be carried outside of games, improving the players perspective not just on educational games but on learning in general.

Learning through fun is optimal when the challenge level matches the skill level of the player. In learning that means being able to adapt the challenge to a baseline level and gradually increase the challenge until there is resistance. The hope is that the fun incentivizes the player to push through that resistance and establish a new upper bound. Learning by doing is natural to humans and doing it as a game that rewards the player is an extension of that behavior.

Authenticity refers to the actual nature of the learning act, meaning we are not just presenting information without context but instructing within a contextualized framework. We do this by grounding our teaching in specific settings and educational methods.

Independent play means we are self-reliant, can explore and deviate from the existing path and still be rewarded.

Learning by doing is the complement of Learning through Fun. You virtualize the activity or gamify it, and now the digital activity replaces the real interaction, at least for the purpose of instruction. A virtual classroom where you can solve problems online is an example. You have to be able to interact with the environment, and this is where games are most effective.

The 8 mechanisms of game-based learning are Rules, Goals, Background or Setting, Challenge, Interactivity, Uncertainty, Feedback and a Social element (Perrotta et al., 2013.)

'Rules, Goals and Challenge' govern how the player interacts with the game and gives direction and parameters. The setting and interactivity gives context to the player experience, what it means and how it happens. Uncertainty and Feedback define the outcomes and inform the player on how to proceed and the social element allows the player to interact with others and to compare to other players in a similar activity.

2.4. Successful Strategies in GBL

According to Bartle's Psychology of the player, (2004) there are four player types. These are Achiever, The Explorer, The Socializer and the Killer. Achievers focus on obtaining prestige and status and crave progression-based systems. Games can focus on achievers by incorporating Rewards, Badges and Scores that can be shared on leaderboards. Players have responded favorably to Achievement systems incorporated in games (McDaniel, Lindgren, & Friskics, 2012) since the Microsoft Xbox first introduced them in 2010, and now most major gaming platforms include some kind of Achievement, Trophy or reward system. These reward mechanisms are essentially feedback systems that can help communicate to the learner when he has achieved specific objectives. Achievers are roughly 1% of the player population.

Explorers are focused on discovery, and ultimately play games for content. They want new experiences and will want to test your game to see what's possible. They represent roughly 10% of all players currently and that may increase, as games shift their models from one-and-done releases to content-as-a-service models or games-as-a-service where they developers hope to continue

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monetizing their platforms over time with new content. For learners this means adding additional learning material so that the learning journey never ends.

Socializers focus on comparing themselves to other players. They want to interact in a community and they want to have a unique identity. Social features that allow them to communicate with other players and compare themselves to others, as well as differentiate themselves work best. One manifestation of this is the need to customize their experience, whether it's their player avatar or having other differentiators that denote rarity or uniqueness (Bartle, 2008). Approximately 80% of players are socializers. For learners statistics beyond their own social or academic circle may help increase motivation and also set expectations for learning outcomes.

Finally, we have the Killers. They play the game as a zero-sum sport; their gain is the loss of another. They are very competitive and winning is the driving factor. Killers typically look for a competitive advantage, and this is traditionally exploited in monetizable games. In education, we want to use feedback mechanisms to promote healthy competition; not just against other learners but against the player itself, creating a positive feedback loop where score improvement is rewarded and encouraged. These are what are considered to be the hardcore gamers, and while an interesting player type they represent the minority of players (approximately 1%.) (Kumar et al., 2020.)

The most successful strategies and the most successful games in general are deliberate about their player types and try to target through game-play and design all 4 groups. This way the game offers something for everyone and the expectation is that learning can occur as a result of simply playing the game.

3. Results

Creating a Digital Game-Based Learning Game focused on Arithmetic Training

The idea that children learn by playing is not a controversial one. Indeed, Children should be active in their learning experience (Bird & Edwards, 2014), and by constructing a game where they can interact and receive feedback, the hope is that the learning cycle is sublimated by the form of game play, and that learning will occur without a conscious effort.

Learning through play does not require the player to have a specific goal in mind or to complete a specific task in order to receive feedback. For a player to gain the most from the experience they must develop their intuition and become knowledgeable about the game world in which they interact within (DeSouza & Jagmohan, 2005). Educational games that use simulation or problem solving require a high level of interaction between the user and the computer system. These interactions must be seamless and intuitive to ensure an enjoyable and engaging user experience. This is why it is important for the designer of the game to understand the specific needs of the learner and create an environment where they can develop the necessary skills and knowledge to become successful (DeSouza & Jagmohan, 2005). Another important aspect of a game-based learning environment is the extent to which users are allowed to explore the environment and interact with content at their own pace. This will allow the learners to progress through the curriculum at their own rate and focus on areas of difficulty so that they have a better understanding of any concepts that they find difficult (Lee & Tsang, 2009). This also means that there will be no pressure for the player to complete a level of the game before they can move on to the next one.

Previous research has shown that people generally perform better in a game if they have a strong sense of control in their experience (Blumenfeld et al., 2003.) This means that they have the opportunity to set their own goals and make decisions about how to accomplish them. For example, if the player has access to a variety of different power-ups then they can choose the one that they feel is most effective and use it to pursue their goals throughout the game. The game will also provide them with feedback that will help them to adapt and adjust their strategy to achieve their goals. By allowing players to determine their own goals in this way the game promotes learning and engagement by providing them with an opportunity to achieve a sense of mastery over their situation (Blumenfeld et al., 2003). This allows them to develop a deeper understanding of the concepts and skills that they are using in the game and apply them to other areas of their learning journey.

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Another approach to game-based learning is to use gamification techniques to motivate and engage learners in the classroom (Jang, 2017). In this approach, players are rewarded or penalized depending on their success in the game or by completing certain tasks. In this way they are motivated to continue playing the game and they are encouraged to try again if they fail to achieve the goal the first time round. This approach can also be used to encourage players to try new strategies to help them achieve their goals which will help them to develop their problem solving skills (Reimert & Wunderlich, 2010).

in learning and practicing math problems. Children often use them to drill basic arithmetic problems or to learn new sight words, but they are not inherently fun exercises. Games can prove to be an excellent resource to make something more fun, and playing flashcards as a game can have several benefits. For one, we can keep track of our scores and our performance in general, and perhaps create incentives to try again in order to improve our scores. We can do this by borrowing ideas from Gamification. Gamification is the concept of applying game design elements to non-game contexts in order to make it more appealing and fun. It is usually used in non-game contexts, like in marketing for example, where the elements of games are brought in to make the marketing activity more appealing to the user.

There are many different ways of using gamification in educational contexts and they can certainly be used in games to bring in elements from outside gaming and make them compatible. Gamifying flash cards is not just about implementing them in digital form and using game systems around them. It is also about abstracting the essence and using it in a more appropriate form. For example, the game portrays malfunctioning robots running around a moon base. In order to fix the robots, the user must answer the puzzle, or in this case, the arithmetic problem, embedded in the robot's screen. In this way the flash card's contents has been transported into the robots, and solving the problem will disable the robot so it can be repaired. In this fashion the user can be solving as many flashcard problems as he can within a limited time window, without ever knowing he is solving flashcards. By tracking his score and creating incentives we encourage the user to keep trying to improve his scores and to make it further into the game. This same system could be used for sight words with slight modifications, and with algebraic equations among other ideas.

It has been said that feedback is one of the most important tools an educator can have in their toolkit. It can be used to improve student achievement and learn more about their strengths and weaknesses. There are many different kinds of feedback that can be given to students to help improve their learning and achieve their goals.

When feedback is delivered the best results occur when it is timely, specific, and actionable. In the context of mathematical games, being able to know what went wrong, what went right and how to improve is key to the educational process. The very first form of feedback, and the most simplest is the score. Once we complete a level, we can calculate the correct answers and give percentages. A desired next step would be to give specific feedback to the player regarding how to improve their score. Perhaps if they scored poorly in a certain type of problem (say division) this can be highlighted for them to let them know to practice division more versus other problem types where they have achieved a better score. A good feedback mechanism will try to do 3 things. It will display the concept in order to reinforce knowledge, it will explain and correct any misunderstandings and it will prompt the learner to follow up on the appropriate concepts to address the issue (Yang & Lu, 2021.) Mastery will be obtained by replaying levels and trying to improve scores. A leaderboard will show the players with the highest scores per level, further incentivizing the player to attempt to improve their scores.

Achievements and badges have become a staple of modern game design. Virtually every console or game service features them or a trophy system. The point being to hit certain gaming milestones and commemorate them as achievements. An in-game achievement is an unlockable that becomes permanently bound to the player. They feature the name and description of the achievement, and also the date when they are unlocked. Some systems will award points to each achievement, or some kind of tier-based system, to show that some achievements are harder, and thus more valuable. One way to compare players in a game is to compare their scores, such as in a leaderboard. Another way

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is to compare their achievements or badges. This way a player that has a lower score than another can still compare favorably to another player if they have a particularly rare achievement. In fact, achievements have even been used outside of games, like in a photo sharing app (Montola et al., 2009) as a means to gamify an application and make it more compelling. The point is that games need incentives for players to perform actions and strive to their objectives (Bjork, Holopainen, 2005) There is a certain taxonomy to achievements as follows.

'Instructors' are achievements that educate the player on how to accomplish something. 'Quests' are awarded for completing a specific objective in the game. 'Content Discovery' are meant to entice the player to try specific components of the game, perhaps out of the ordinary. 'Social' achievements reward interaction among players. 'Secret' achievements are awarded for finding secret areas or items. 'Grind' achievements are the ones where a task is typically repeated multiple times, such as obtaining a large amount of gold or something similar. 'Difficult Tasks' are awarded for overcoming a particularly difficult challenge.

There are more types of trophies and achievements (Galli & Fraternali, 2014) but these are the most common types and enough to serve as a design pattern for creating new achievements in educational games

3. Research

In order to test the efficacy of Game-Based Learning, as well as the game as a tool to improve results of arithmetic testing, a small study was designed, using a questionnaire that asked the players questions in the areas of their experience, learning motivation and design. The results are attached separately, along with supporting information and analysis.

The instruments were used to attempt to generalize the findings given a large number of students. The questionnaires helped validate the results, particularly in the areas of learning motivation.

The study used a mathematical game which implemented the game-based learning elements discussed in this paper. It focused on arithmetic problems and providing feedback to the student on their performance.

It is considered a modern computer game, using 3D graphics and a modern interface to facilitate learning (Kebritchi, 2009), and can be easily extendable into other problem types, even outside mathematics. The game starts with an introduction into how it's played and the objectives, and then starts the player off, interacting with robots that have equations in their face. These robots are aggressive to the player, and the player can fix them by solving the equation displayed. Every level can use different operators and increase the number of enemies, and the difficulty can be adjusted in several ways.

The game captures the performance of each student and stores it in a local file. The contents are stored in a cloud repository anonymized, in order to better aggregate the data. The questionnaire was administered separately. Motivational measurement was done by measuring four major attributes, in line With Keller's ARCS (Attention, Relevance, Confidence and Satisfaction) model.

Attention refers to if the student's interest levels increased or not during the activity. Relevance refers to whether the activity is perceived to be important to the student. Confidence refers to whether the student thinks they will be successful. Satisfaction refers to the payoff that the student expects to obtain from the activity.

4. Conclusions

In view of the enthusiasm that digital game-based learning can offer, this study has explored many of the unique opportunities that it can bring to digital education, by tailoring the content and its feedback to the individual user, by providing regular input and fomenting user motivation and by constantly engaging the user to come back and play some more. The act of playing is the act of learning and this is reflected in mathematical learning, specifically in the arithmetic domain that the game is applied to. While the game has been shared with a large group of elementary students, the author believes that to truly capture the attention of all students several games in different genres

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and with different game dynamics need to be developed since any one game will probably not appeal to all potential users.

In view of the results that traditional class-based learning cannot provide satisfactory results in motivating students and improving their mathematical performance, there is a need to examine alternative methods of teaching and learning mathematics that could promote higher retention rates and increase student success in mathematics. Many studies have identified the potential of game-based learning as a means to increase engagement and motivation for the subject material. As a result, there is growing interest in the use of games in the classroom to develop not only critical thinking skills but also positive attitudes and attitudes toward mathematics among students. However, the effect of GBL as a teaching strategy continues to be contentious among researchers. There are still many unanswered questions and many areas of research to continue to explore. However it is clear that digital game-based learning adds an element of fun and interactivity to the classroom which may help to engage learners and boost their interest in the subject matter. The results indicate that by using the GBL approach students gained significant improvement in their confidence toward mathematics, with some modest gains in performance which could potentially be improved by using the software for an extended period of time. Most players also exhibited an increase in motivation to continue to work in math and noted they would be willing to engage with educational games in the future.

This study has pointed out some of the benefits of GBL but it was still small-scale and of a short duration. Further study with a larger sample and with more time to track improvement needs to be done for additional evidence and support.4. Discussion

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

Appendix A

Playtest Script

Background

“You are stranded in a space base, and the only way to get home is to successfully repair the robots in the base so they can help you repair your spaceship and you can get home. In the first level, broken robots will spawn and attack if you get too close! To repair them, you will have to lock on to a robot, answer the question on their screen and pick the correct answer! This will disable the robot. Try to disable as many robots before the time runs out.”

Instructions

The first screen describes how to play. Press F1 to disable or enable the help screen. Try to disable as many robots before the time runs out and don’t let the enemies take all your health away. You have 4 levels to play where you must disable all the robots to continue. Between levels you will be teleported into the base where you can buy power-ups for the next level.

Do not let the enemies touch you or surround you, if they do, they will harm you and if you lose all your health you will be disabled.

Levels are roughly 2 minutes long so the entire experience should take less than 10 minutes to play. Each level will have different types of arithmetic problems.

Questionnaire

Questionnaire (User Experience)

(Answer 1-5 depending on how strongly you agree with the sentiment: 1, I strongly disagree, 3, neither agree nor disagree, 5 strongly agree)

1. How well do you understand the controls?
2. Can you lock onto an enemy and solve the equation?
3. Can you disable all the robots before the time runs out?
4. Are you dying to the robots?
5. Did you have a problem with the control scheme?
6. Did you encounter any bugs or problems?

Questionnaire (Learning Motivation)

(Answer 1-5 depending on how strongly you agree with the sentiment: 1, I strongly disagree, 3, neither agree nor disagree, 5 strongly agree)

1. Do you agree math games are a good way to learn math?
2. Did you have fun while playing the game?
3. Would you play again to improve your score?
4. Were the math puzzles you solved too hard?
5. Was the number of enemies appropriate?

Questionnaire (Design Specific)

1. Does navigating the world support the implementation of game feel?
2. Is the difficulty level appropriate?
3. Are the powerups enhancing the game experience?
4. Is the goal of the game clear?

Playtest Results

Introduction

This document consolidates the results of our play test as well as the justification of those questions and the analysis of the results. The author playtested with 10 different individuals going over 15 different questions, spanning areas like design, user experience and user motivation.

Justifying Playtesting Questions:

Design Questions:

- Does navigating the world support the implementation of game feel?

  A lot of the design choices made were around the implementation of the "Game Feel" requirement so I was sensitive to feedback in this area. This question required explaining to the player what constitutes game feel.

- Is the difficulty level appropriate?

  There was some tuning of the difficulty prior to playtesting, and the overall time per level was increased and the number of enemies was drastically reduced as a result.

- Are the powerups enhancing the game experience?

  I spent a lot of time working on "interesting choices" by allowing the player to collect and buy power-ups throughout the game. Once the player has the power-ups, do they understand how to switch between them and use them? The purpose of this question is to see if they understand everything around power-ups.

- Is the goal of the game clear?

  I worked on the game for a few months now and clearly understand the objectives and goal of the game. This question was to help us see if the game is actually clear to the player, in the sense that it's easy to understand that you have to disable all the robots in order to move on to the next level.

  User Experience:

- How well do you understand the controls?

  For the alpha version of the game, I added an overlay to the game world that shows the controls the player uses to play the game. This question was to see how well those explanations worked to teach the player how the game works.

- Can you lock onto an enemy and solve the equation?

  The main interaction with the robots to play the game is through locking onto enemies to disable them. This question is trying to check that this main mechanic is clear and works well for the player.

- Can you disable all the robots before the time runs out?

  In order to pass off the current level and move on in the game, the player must disable the robots in the given time. Since this is a main way the player progresses in the game, I needed this question to make sure they understood this mechanic and that they were able to accomplish this on each level.

- Are you dying to the robots?

  One of the ways you fail to complete the current level is by having the robots hit you or answering the questions incorrectly, both reduce your HP causing the player to die and restart the level. Is this happening a lot? Is it too easy and never happens?

- Did you have a problem with the control scheme?

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I already made sure they understood the control scheme in an earlier question, but this question targets and issues with the control scheme. Is it hard to use? Are there too many controls that make the game artificially more difficult?

- Did you encounter any bugs or problems?

For the final game I wanted to improve on the above questions and fix any bugs the play testers found during their time playing.

Approach to testing design questions and Playtest Methods

I ran the game for 10 minutes with each player and asked them to complete the survey in the end. They answered all the questions with a 5 point scale. After they answered, I asked clarifying questions to get additional insight. Through these clarifying questions, I discovered that once the controls were understood the difficulty was appropriate and even tended to be a bit easy. In particular, the early levels need to be adjusted to increase the difficulty from the second level on and playtest that in the future.

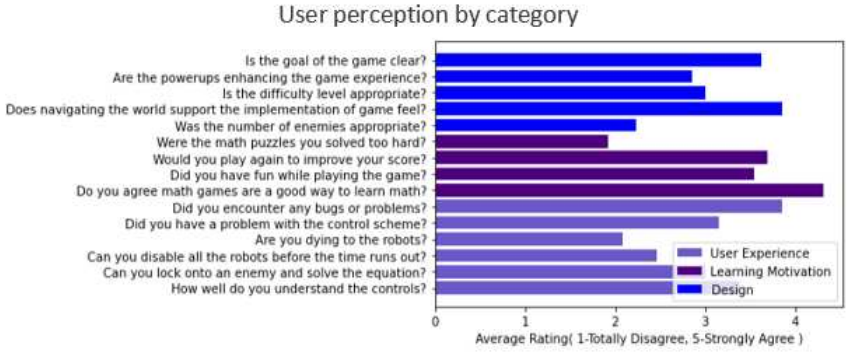
I asked the users about the power ups and discovered that the over-abundance made them unremarkable. It was also clear from the play test that they needed more of a tutorial with the power-ups to understand how to use them to evade enemies (with the raised platform power-up) or kill enemies easier (with the slow time power-up). The game was moving too quickly for the play testers to learn how to use the power-ups during the game. This will be an area of focus for future work.

The answers to the questions and additional feedback received leads us to believe that the goal of the game is well understood by the players. It helps that the objective of the game is very straightforward and there is no unnecessary complexity.

Appendix B

The results from the play test survey were broken down into three distinct graphs. The first graph focuses on the questions split into the three categories I was targeting (user experience, learning motivation, and design). The second graph shows all the responses for each question to highlight which areas need further focus.

The highest rating from the questions is in the learning motivation category. The play-testers felt that the puzzles for each level were an appropriate testing difficulty and strongly agreed the questions are an effective way to learn math. It was also clear that solving the math problems this way was an enjoyable experience. The lowest rating received was in the user experience category. I



found that the play-testers rarely died from the robots and it was easy to disable them all before the time ran out.

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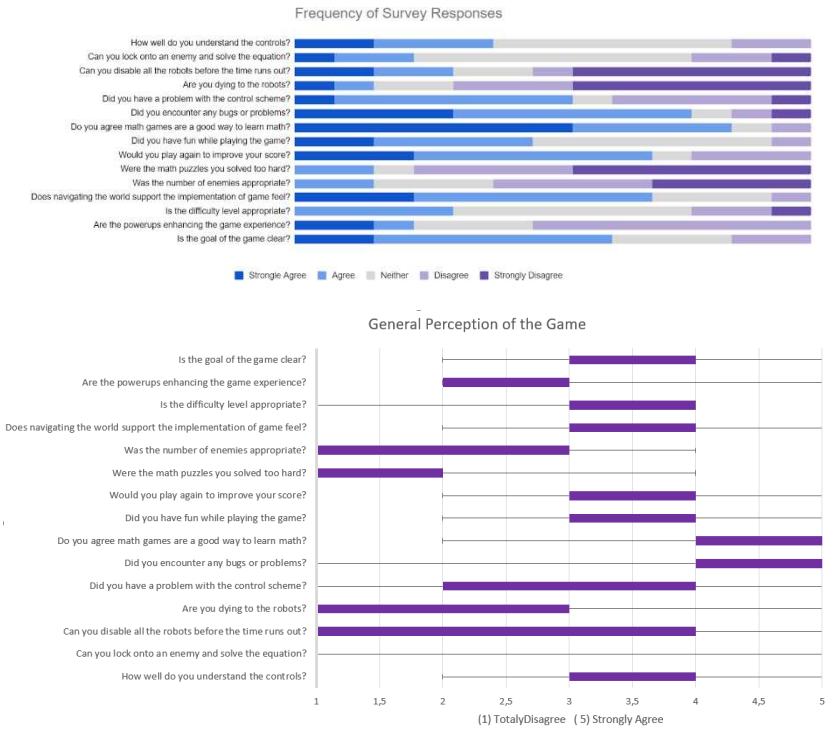
The strongest responses here showed that the math problems for the play-testers were not too difficult, were a good way to learn math, and that they didn't die from the robots (this prompted us to improve the experience with the robots to have more of them and chase the player more). The goal of the game was shown to be clear to the play-testers (disabling the robots in the time given). I also found that the play-testers enjoyed jumping around the world and on top of things to escape the robots.



The general perception of the game shows that there are two biggest items to address in the future, the numbers of robots and the number of bugs, which represents the biggest flaws among the play testers. Additionally, the answers varied greatly from one another, for instance there are 6 questions that presented each of the options possible, and other ones presented 3 of the options possible meaning that the game does not present a general consensus between the users.

Action Items and Future Work

Fine tuning the difficulty of each level is a work in progress. The author believes increasing the number of enemies will make the levels a bit more challenging and make the power-ups more useful. In addition to adding more enemies, I will increase the following distance so the enemies more aggressively target the player, increasing the need to use power-ups in an intelligent way.

The power-ups need to be made scarcer and more valuable. I plan to decrease how often the enemies drop power-ups and make it more common for the enemies to drop coins which can then be used in the moon-base to purchase power-ups for the next level.

The control scheme is functional once the player becomes accustomed to it, but the game would benefit from having more than one scheme. One option we implemented is to add the keys '1' through '4' as a secondary method of selecting the correct answer.

Playtest Data.

Question	Player	Player	Player	Player	Player	Player	Player	Player	Player	Player	Player	Player	Player
How well do you understand the controls?	3	4	3	3	3	4	2	3	2	4	5	5	3

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Can you lock onto an enemy and solve the equation?	4	5	3	2	3	3	3	3	1	2	4	3	3
Can you disable all the robots before the time runs out?	5	5	2	1	4	3	4	3	1	1	1	1	1
Are you dying to the robots?	1	1	1	1	2	2	1	2	5	4	1	3	3
Did you have a problem with the control scheme?	2	1	4	5	3	2	4	2	4	4	4	2	4
Did you encounter any bugs or problems?	4	2	5	4	5	5	4	3	1	4	4	4	5

Question	Player	Player	Player	Player	Player	Player	Player	Player	Player	Player	Player	Player	Player
Are math games a good way to learn math?	4	5	5	3	4	5	5	4	5	5	5	2	4
Did you have fun while playing the game?	4	5	3	2	3	4	3	3	4	3	5	3	4
Would you play again to improve your score?	4	5	4	2	4	4	4	4	5	2	5	2	3
Were the math puzzles you solved too hard?	2	1	3	1	4	2	1	4	1	2	1	1	2
Was the number of enemies appropriate?	3	1	2	2	4	4	2	3	1	1	2	1	3
Does navigation support the implementation of game feel?	3	4	4	4	3	4	4	4	5	5	5	3	2
Is the difficulty level appropriate?	3	4	4	2	4	3	3	3	4	2	1	3	3
Are the powerups enhancing the game experience?	2	4	2	2	2	3	5	3	5	3	2	2	2
Is the goal of the game clear?	3	4	5	4	3	4	4	4	3	5	2	2	4

General Results: (1-Totally Disagree,5- Strongly Agree)		
Question	Average	Standard Deviation
How well do you understand the controls?	3.384615385	0.9607689228
Can you lock onto an enemy and solve the equation?	3	1
Can you disable all the robots before the time runs out?	2.461538462	1.613246448
Are you dying to the robots?	2.076923077	1.320450584
Did you have a problem with the control scheme?	3.153846154	1.214231845
Did you encounter any bugs or problems?	3.846153846	1.214231845
Do you agree math games are a good way to learn math?	4.307692308	0.9473309334
Did you have fun while playing the game?	3.538461538	0.8770580193
Would you play again to improve your score?	3.692307692	1.109400392
Were the math puzzles you solved too hard?	1.923076923	1.11516355
Was the number of enemies appropriate?	2.230769231	1.091928428
Does navigating the world support the implementation of game feel?	3.846153846	0.8987170343
Is the difficulty level appropriate?	3	0.9128709292
Are the powerups enhancing the game experience?	2.846153846	1.14354375
Is the goal of the game clear?	3.615384615	0.9607689228

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