

MathBharata: A Serious Game for Motivating Disabled Students to Study Mathematics

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Abstract—Game addiction is a serious issue. A lot of children play games too much that it hinders their academic prowess. This further makes hard subjects like mathematics to be more difficult for the student. This paper proposes a method to motivate students to study mathematics using a serious game to utilize that gaming addiction to help students instead. Serious game is a game which conveys serious content. MathBharata is a serious quiz game where players can try to answer multiple choice questions with incrementing difficulty. It uses various aspects to entice students to learn mathematics. MathBharata was tested on 85 students of both regular and disabled school. Every student who tested the MathBharata game, including both disabled students and regular students, responded that playing the game boosted their motivation to study more to beat the game, with 29.4% of students responding with “Strongly Agree” and 70.6% students responding with “Agree”.

Keywords—serious game; math; videogame; disabled students;

I. INTRODUCTION

Games are easily accessible with all the technological advances. Easily accessible games such as mobile games increase the number of players and the frequency of players playing their game. Game addiction can easily develop on children and hamper their academic prowess. Difficult subjects such as mathematics are getting harder because the students are not motivated to learn them. To remedy this, this paper proposes a method to use games as a way to motivate students into learning mathematics.

Game is one way to entice students into getting engrossed in something. Games can use various visuals and sounds to make children more excited and willing to study something they usually do not want to. Games can also be given interface and system that entice the students to play more and more, encouraging the students to do their best so that they may be better in the game. This helps in reducing dropout rates from student’s frustration and increased motivation to study [1].

Serious games are games with an additional set of rules apart from a regular game. Serious games need the game to start with a problem to be solved. Players need to be driven to play by the gaming activity itself instead of generating wealth and property. The problems inside the game should also have a correct solution. Last but not least is the game should have something for the players to learn [1].

Serious games can also be used as a medium to assess the student’s competence [2]. This, together with motivating the student to study more with game as a fun medium, makes serious games a great choice to motivate students while the student’s competence data is gathered by the game. Genders should not be a problem since earlier study using games showed that the results gotten from both male and female respondents show little difference [3].

Prior studies of games for education has shown mixed results, where more than half studies shows no difference in learning from games or with traditional methods (38 studies), almost half favors games (27 studies), while only around 5% of the studies reported that traditional methods were better than games (3 studies) [4]. The sheer number of studies supporting games shows that games shows potential in motivating students. Serious games, being games with more concentrated focus, should show more potential in motivating students while also getting them to learn things. A lot of parents and schools still marks games’ help in education as trivial or even only worsening the current state of the child [5]. But the study collected by [4] has proven that games help in education more times than not.

A problem appeared when serious games are used as a method to learn subjects like math, which usually needs calculation before players can choose their answers. In a past study, there were a lot of students who used their efforts into something other than studying math itself. They tried to study the game’s pattern instead, to achieve better score easier than before. The fun in the games might provide motivational support for the children to study more, but the habit to do wild guesses and seeking fun will sometimes hamper the progress of the children [6]. This is why the fun aspect should be directed to lead the students to study and try to solve the questions right, rather than distracting the students and making them try to find an easy way out of the problem.

II. QUIZ GAME

A. Competence Structure and Mathematics

The basis for competence structure is retrieved from the competence structure of elementary schools in Indonesia. The aforementioned structure detailed the competence for each class. The competence structure is then used to classify questions taken from the mid-term and end-of-term tests of Indonesia’s elementary school to determine the connection between each

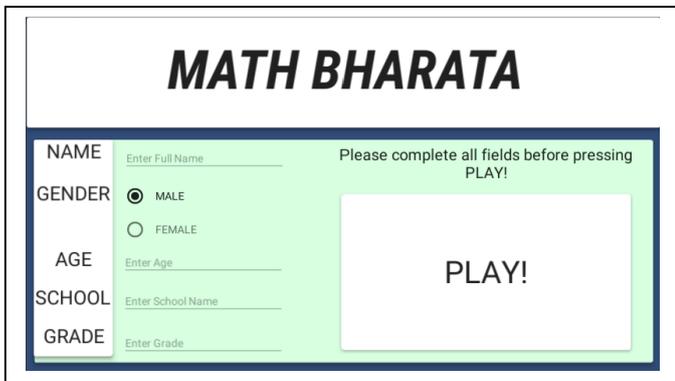


Fig. 1. Title screen of MathBharata game

competence and to make a database for questions used by the MathBharata game.

B. Determining the used competence

To narrow down the competence and the relationship between competencies, MathBharata used only 2 competence from each class levels, spanning 12 total competencies for 6 classes of elementary school. The competence points used are “Amounting the number of things”, ”Calculating addition and subtraction of numbers until 20”, “Calculating multiplication of numbers that results in two-digit numbers”, “Calculating mixed operation”, “Calculating addition and subtraction of three-digit numbers”, “Calculating multiplications that result in three-digit numbers and division of three digit numbers”, “Calculating advanced mixed operation”, “Calculating addition of fractions”, “Converting percentages to decimals and vice versa”, “Calculating multiplication and division of fractions”, “Calculating mixed operations, including Greatest Common Divisor and Least Common Multiple“, and “Determining mean and modus of data.”

The competencies are related to each other in that all of them calculates numbers in some kind, instead of other competencies that, for example, concerns two-dimensional figures or three-dimensional figures. The intent is to focus the competence analysis in numbers first as preliminary data are collected to better the accuracy of the analysis.



Fig. 3. Game screen

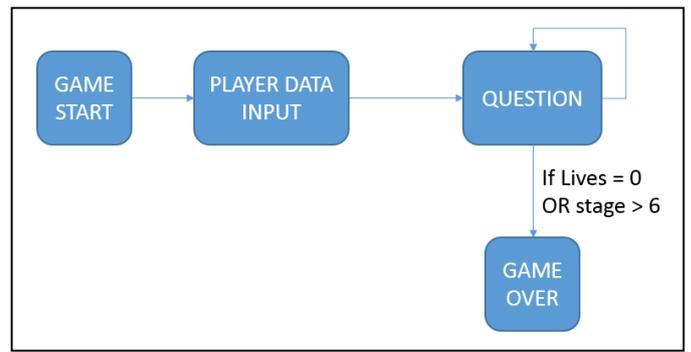


Fig. 2. Game flowchart

III. GAME DESIGN

A. Interface Design

MathBharata is a Unity-based game, built as a quiz game. The game starts on the Title screen as shown in Fig. 1. The title screen features fields to input the player’s data to log for development purposes. The recorded data are the player’s name, gender, age, institution name, and education level. The data is then written into a log, which also records the player’s answers, time needed to answer, and whether they are correct or not. This log and the questionnaire filled by the player after the game ends are the analyzed data for this research. The questionnaire asked the player’s impressions of the game’s aspect for further development. The flowchart showing the flow of the game can be seen on Fig. 2.

The second screen as shown in Fig. 3 which will be the main game screen is comprised of a question, 4 answer choices, a timer gauge, and a set of display displaying the player’s current life, stage, and number of questions left.

MathBharata’s game design is intended to be simple and crisp. This is because even fantasy-themed violence like the usual knights fighting dragons in fantasy games still tend to give negative short and/or long-term aggression in the children’s minds [7]. Playing games with violence in it can also impact the children’s pro-social behaviors negatively [8]. Such behaviors must not be implanted on children, so violence in all forms, even fantasy-themed ones, are not deemed to fit in the serious game. Any form of contact with violence in video games may cause desensitization to violence, which in turn makes children more prone to do violence themselves [9].

B. Software Design

The game offers 4 options to choose as each question appeared. The player starts with 3 lives, with max lives of 5. Each correct answer increases the player’s life by 1, where each wrong answer decreases the player’s life by 1. When player’s life reaches 0 the game ends. The game questions consist of a total of 60 questions, spanning 6 classes of elementary school with 10 questions each. Each competence has 5 questions, with a total of 12 competencies in the game, as mentioned earlier. The time allotted to answer each question is 120 seconds.

The game design gives 5 lives and 120 seconds to answer the questions, since disabled students tend to need more time to calculate the answer of a question and are more prone to calculation mistakes.

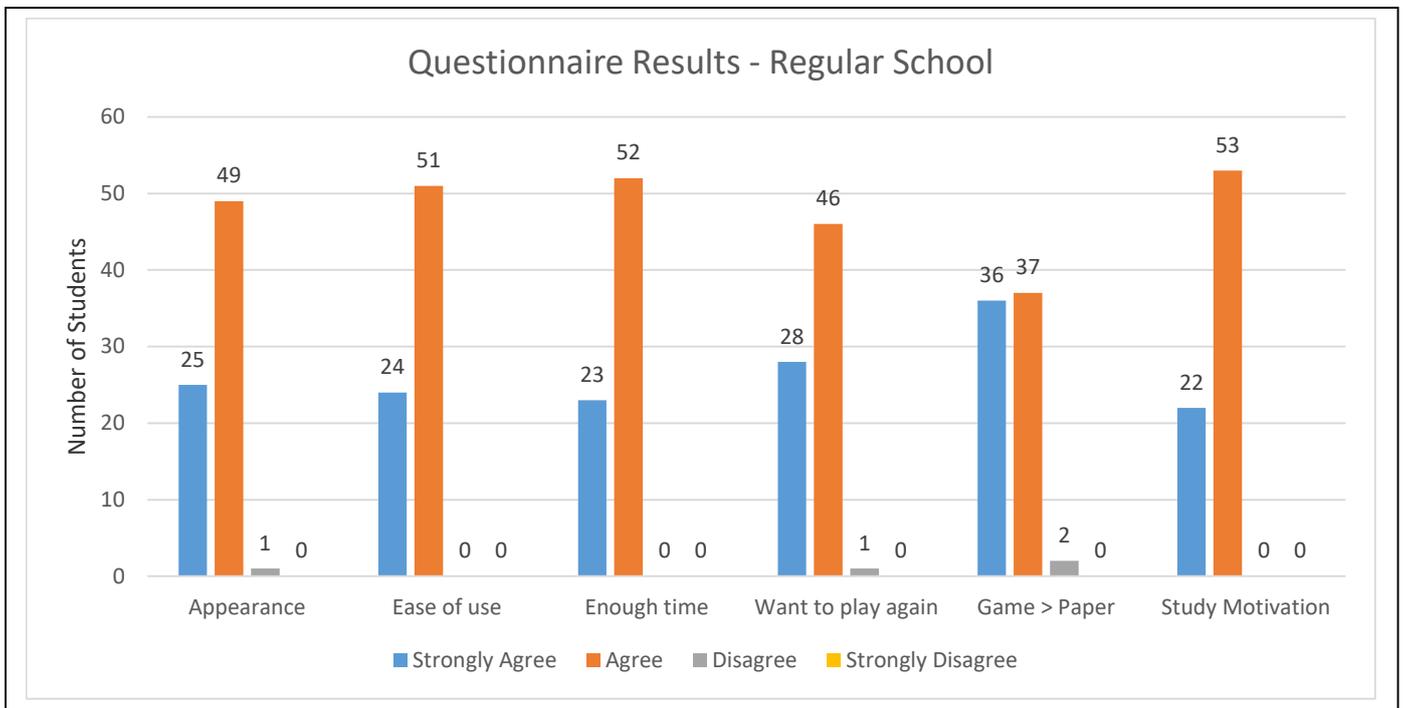


Fig. 4. Questionnaire result chart of regular school

The game's database uses the XML data model to ease the process of changing question contents for future uses. Descriptions on each data field also ease people with no experience with the program to change the contents as well. The game's log uses the TXT data format to ease reading the data. The log also reports what level was the player last on.

C. Question Structure

MathBharata is comprised of 5 questions per competence. Each question should be answered by the player in 120 seconds. If the player fails to answer within the allotted time, one life will be deducted. Ten questions for the grade, starting from grade 1 questions, are presented in random order to the player. After the player successfully survives all 10 questions, the player will enter the next stage, with the last stage being stage 6 containing elementary school grade 6 questions.

Questions used inside the game mostly consist of just numbers instead of using sentences to explain the settings of the question. This is because disabled students, particularly the ones with Intellectual Disability, have troubles processing long sentences and their meaning. This makes it hard to give them story-based questions, hence why most of the questions are in numbers-only format.

D. Used Technology

MathBharata is made mainly using the Unity game engine. Unity is a free game engine that lets the user create both 2D and 3D games with ease. Games made with Unity can also be deployed with ease to multiple platforms [10]. MathBharata used the 2D mode of Unity Engine to create the game in 2D. The programming language C# was used for the scripting of the game in Unity [11].

E. State-of-the-Art Serious Math Games

There are various serious games already available for regular students to play and enjoy. Those games' designs have also been used as a consideration in making a serious game to motivate disabled students. However, after discussions with the principal of the disabled students' school, the designs of MathBharata was modified to be more suited towards disabled students, particularly Intellectual Disability students.

The first serious game discussed was SPENT [12]. SPENT is a decision-based text serious game which gives the player options to do during their lives inside the game world, which will affect the outcome of the player's life in the game. The game is deemed unsuitable for disabled students since most of them have trouble understanding series of sentences.

The second serious game discussed was HELP Math Program by Boulder Learning [13]. The design of the game itself is colorful and carries a lot of variety. Regular students would have loved the game a lot since the designs keep the children from getting bored of the game. The problem with disabled students, as mentioned by the principal of the disabled school, is that a game that has too many things other than the main objective itself tend to make disabled students sidetracked for a long time. That is why a simpler look is used for MathBharata.

Another serious math game called Mathbreaker was also discussed [14]. Mathbreaker is a serious math game where players move around in a 3D world, with blockades or enemies that require the player to use calculations to finish or defeat. The interactive and colorful gameplay already gave great results according to the creator, as mentioned on the site. But the main problem with disabled students is that their math abilities mostly consists of additions, subtractions, and multiplications.

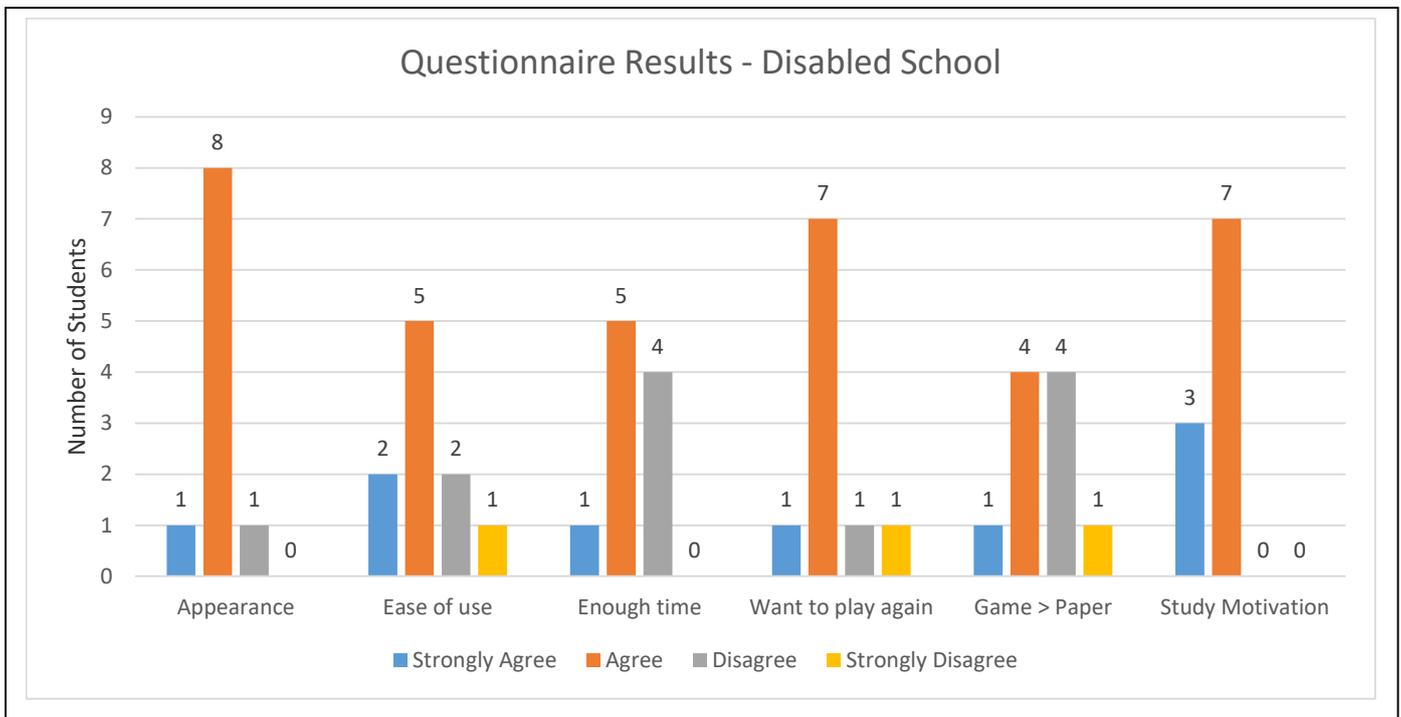


Fig. 5. Questionnaire result chart of disabled school

The game sometimes requires the player to use factorization to get the answers they need from the available choices, hence why disabled students would have trouble finding the answer since it is not laid clearly in front of them. MathBharata took a simpler approach by laying out the available choices to make sure the disabled students don't get confused by the question and choices.

IV. GAME TESTING

The MathBharata game was tested on 85 children, of which 75 originates from a regular school while the other 10 children are from a disabled school. The students from regular school are in their fifth grade of elementary school, while the disabled school students vary from 8th grade to 12th grade because of their differing cognitive abilities. All respondents are asked to fill in a questionnaire where they answer their impression on the questions given about the MathBharata game. Questions asked includes "You liked the appearance of the game", "It was easy

to operate the game", "Time provided to answer the questions were enough", "You wanted to play this game again in the future", "You liked this game-based test more than paper-based test", "What do you feel after playing the game", and "You feel motivated to study more after playing the game".

All participants were asked to play the MathBharata game. After they have reached a Game Over, they are asked to fill in the questionnaire given to them through an online form. The questionnaires are then recorded, compiled, and analyzed for developing purposes.

For the question "You liked the appearance of the game", 26 students answered "Strongly Agree", 57 students answered "Agree", and 2 students answered "Disagree". This shows that around 97% of the sample student loved the design of the game. The question "It was easy to operate the game" got 26 students answering with "Strongly Agree", 56 on "Agree", 2 on "Disagree" and 1 on "Strongly Disagree". A worthy note is that the 3 students who disagreed with the statement were from the disabled school. The next question, "Time provided to answer the questions were enough", garnered 24 "Strongly Agree", 57 on "Agree", and 4 on "Disagree". The 4 students who chose Disagree were all from the disabled school. "You wanted to play this game again in the future" got 29 in "Strongly Agree". 53 on "Agree", 2 on "Disagree" and 1 on "Strongly disagree".

The most awaited question, "You liked this game-based test more than paper-based test", a surprising number of 37 answered "Strongly Agree", while 41 others voted "Agree". However, there are 6 "Disagree" and 1 "Strongly Disagree". The disagreement came mainly from disabled school student, which were less trained on computers. When they were questioned further about the reason, they all said it was because using computers are hard for them.

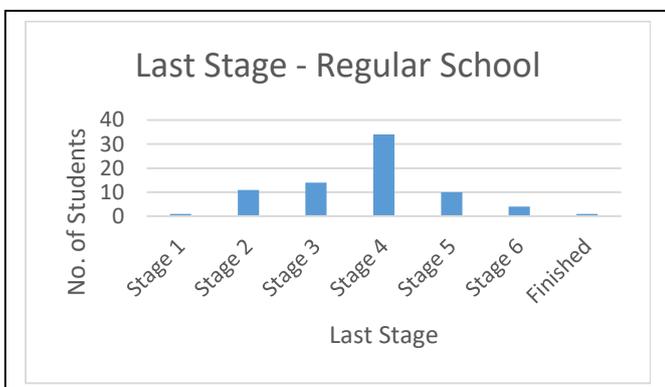


Fig. 6. Last stage achieved by students of regular school

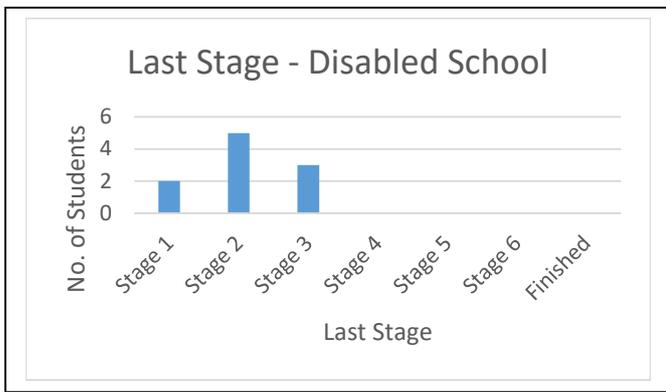


Fig. 7. Last stage achieved by students of disabled school

Whether they liked the game better than paper tests or not, a great number of 83 out of 85 students answered they are “Happy” after playing the game. The other 2 answered with disappointment, which when questioned further stems from not being able to finish the game’s all 6 stages. The last question about whether they want to study more or not after playing the game got no disagreement at all. Twenty-five respondents strongly agreed, while the other 60 agreed that they want to study more for various reasons, like to better themselves before challenging the game again.

The number of each answer for each question for the 75 regular school students can be found on Fig. 4. Based on the very high percentage of agreement of more than 90% for each question, the students are very excited about a serious game that can help them study math. This also reduces the teachers’ workload and eases the data gathering to analyze each child’s competence.

For the disabled school students, the number of answers can be seen in Fig. 5. Half of the disabled students liked paper tests more than tests using games. From the other question’s results, the biggest factor seems to be because they feel that there is not enough time to answer the questions, because as much as 4 students said they disagreed with the statement “Time provided to answer the questions were enough”. The second biggest reason seems to be because they had trouble operating the software, as the question “It was easy to operate the game” got 2 “Disagree” and 1 “Strongly Disagree”. The least troubling aspect seems to be the game’s appearance, as the “You liked the appearance of the game” only got 1 “Disagree” out of the 10 students of the disabled school.

Fig. 6 shows the last stage that the regular school students manage to reach on the game before getting a Game Over. Stage represents the grade difficulty of the questions of the stage. For example, Stage 3 means the questions on that stage are meant to be for 3rd grade of regular elementary school. One student got game over on Stage 1, 11 on Stage 2, 14 on Stage 3, 34 on Stage 4, 10 on Stage 5, 4 on Stage 6, and only 1 student out of the 75 students managed to finish the entire game. Seeing that the students are from Fifth grade of regular school, the modus of the data being Stage 4 shows a relation because the players were yet to pass halfway of Fifth grade. That is why most students have best understanding of materials of the Fourth grade. The average stage achieved of all regular school students is 3.76. This also

supports the above statement because the average nears 4, which seems to be where most of the students’ competence average on.

The last stage achieved for disabled school students are contained in Fig. 7. There is a total of 2 students who finished on Stage 1, 5 students on Stage 2, and 3 students on Stage 3. Disabled students’ cognitive abilities differ to one another, even on the same educational level. The 2 students who finished on the 1st Stage were from 8th grade and 9th grade. The ones who finished on Stage 2 were from 8th grade, 2 from 9th grade, 1 from 11th grade, and 1 from 12th grade. There is 1 8th grader on the Stage 3 achieved group, alongside 2 11th graders. They also had trouble with the allotted time to answer, as seen in the questionnaire results. The average stage achieved for the 10 students of the disabled school is 2.1.

V. CONCLUSION AND FUTURE WORKS

The game motivates students who used it to study more for various reasons, such as wanting to beat the game or wanting to beat their friends’ scores. MathBharata was liked by the regular school students as they have no need to write the answers manually and they were able to operate computers just fine where the disabled school students’ response were mixed because of the allotted time to answer and the inability to use computers easily. A lot of disabled school students experienced trouble on using the computer to play the game since they are not really used to playing games on computers, and some of them still failed to finish calculating the problems in the 120 second time limit. This game also eases and makes the process of data gathering to study the children’s competence more efficient, because the log provided by the game can be used to show the average level of the students’ knowledge. The children like to play the game, helping their willingness to cooperate in data gathering for analysis. The recorded logs also help the efficiency of analysis time, since the data doesn’t need to be gathered manually. The game makes children more eager to study and try to beat the game in the process.

Based on the results, because of factors such as troubles in using computers and difference in study competence targeted for the regular students and disabled students, disabled students had trouble adjusting to the competence asked by the game and answering the questions in the given time limit.

Future works may include the ability to present the student with questions that are not yet mastered by the student as analyzed by the system. There should be no need to manually assign questions as the system will analyze which competence point should the student be studying more. In order to achieve that, a game system which can implement data analysis of the log is very important. The game will immediately analyze each answer and give out similar type of questions until the student in question is deemed to master the current competence. The game should also feature intermezzos for the student so that they are not tired from the questions. The intermezzos might also be modeled after mathematical problems, such as minigames where the students solve basic geometry problems or the likes. These should serve as a mean to prevent student losing motivation while also bolstering the basics for the topic. Future works should also consider seeking a better time limit allocation for disabled students to better accommodate their

calculation ability and thus getting better results while also motivating them to play the game more.

Some factors that may entice players to keep on playing games includes Satisfaction, Flow experience, Interaction, and Value. Satisfaction is a measure to the contentedness of the player after playing the game in comparison to their expectation of the game. Flow experience is an experience where the players feel as if they are absorbed by the activity itself, focusing their concentration on the task at hand, which in this context is playing the game itself. Interaction means the interaction between two entities, whether it is by the player to another player or to a computer-controlled entity. Value is the value the player give to the experience in the game [15]. Three of the factors, which are Satisfaction, Flow experience and Value are visible in the game, as most of the students are satisfied with the game, focuses on the game so much they want to replay it, and likes the game overall. The thing that may be added in future works is the Interaction point. Future works may enhance player experience with multiplayer mode or more interaction between the player and the AI managing the questions.

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