Minus Master: 3d MMOG Game-Based Learning for Improving Dyscalculia Subtraction Skills

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ABSTRACT

Having strong math abilities is a necessary skill for a child to succeed and do well in school. It will present a challenge to students who struggle to process numbers and solve mathematical problems, such as children with dyscalculia. In order to solve this issue, this study offers Subtraction Quest, a 3D platformer game made especially to help children in the 8 to 9-year-old age range develop their subtraction abilities. The game offers a dynamic and entertaining learning experience by fusing entertaining gameplay with instructive materials. Subtraction Quest has two unique stages. The first stage will test players' comprehension of subtraction symbols, and the second will test them by having them answer word problems and basic arithmetic issues. Developed with Unity, the game makes use of educational psychology concepts to improve motivation and learning memory. The effectiveness of the game in enhancing students' subtraction abilities was evaluated through testing. System Usability Scale (SUS), along with pre- and post-tests, was employed to assess user satisfaction with the developed game and evaluate students' performance following gameplay. The results indicate an increase in children's confidence and a strong desire to repeatedly engage with the game. Subtraction Quest can be a valuable tool for educators and parents who are trying to help their children who are having difficulty with this basic mathematical operation by making subtraction practice enjoyable and engaging. Future enhancements may include making the information more age-appropriate and extending the game's coverage of other arithmetic operations.

Keywords- Quest, 3D Platformer game, Dyscalculia, Unity, Game-based learning, Basic Arithmetic

INTRODUCTION

It is impossible to overestimate the importance of fundamental mathematical abilities, especially subtraction, as they provide a foundation for more complex ideas in schooling. Even so, a lot of kids, and particularly those with dyscalculia, struggle to do well in math, which may reduce their self-esteem and academic progress. According to a study from Butterworth et al., about 3-6% of people are affected by dyscalculia, which can seriously interfere with a child's math understanding and often causes continuing issues with school and daily activities [1].

Digital learning environments have become more effective tools for improving student results, particularly for those with unique learning needs, in recent years. Approaches to learning that are interactive and game-based

have been shown to be successful in enthusing students and raising their interest to learn [2]. They allow students to enjoy learning by playing, something that functions as an alternative to regular classroom lessons.

Many children, particularly those with dyscalculia, have a hard time learning simple math, such as subtraction. These students encounter frustration, anxiety, and don't feel confident in their math abilities because the usual ways of teaching subtraction are not suitable for them [1]. Coming up with new answers that fulfil the needs of these students is important to solving these issues.

This study presents Subtraction Quest, a three-dimensional platformer game designed to help kids with dyscalculia become more effective at subtraction. Subtraction Quest seeks to make learning subtraction fun and efficient by integrating academic material with an entertaining game experience. Minus Master is a 3D platformer game developed to specifically address the challenges that children with dyscalculia face when learning subtraction. The game provides an engaging and interactive environment where players can practice subtraction in a low-pressure setting. Educational psychology principles are integrated into the game's design to ensure it not only teaches mathematical concepts but also builds player confidence and reduces math-related anxiety. Through entertaining gameplay, Minus Master aims to transform the way subtraction is taught to children, making it more accessible and effective for those who struggle with conventional methods. The design of the game is influenced by theories of education as well as the expanding corpus of studies on the effectiveness of game-based learning in mathematics education [3]. The game's creation process, its fundamental educational theories, and the outcomes of the game's initial student testing are covered in depth in the parts that follow.

The design and development of Minus Master followed the instructions set by the widely adopted ADDIE model framework. The process explains how to analyse, design, develop, carry out, and evaluate the creation of educational tools. The game was tested with students during its development to ensure its effectiveness and usability. Hence, this study will explore the game's development process, the results of its initial testing, and the potential for future enhancements to further improve its educational impact for children.

Problem Statement

One of the biggest challenges to elementary school students' mathematical development is the prevalence of dyscalculia. These students have special learning requirements, which standard methods of instruction usually fail to provide, which discourages them and makes them lose interest in the subject matter. Moreover, current educational games are not specific enough for dealing with the complexities of dyscalculia. This problem is made harder by the lack of a Massively Multiplayer Online Game (MMOG) specifically designed for elementary school children who struggle with dyscalculia. An MMOG could offer an engaging, flexible, and inclusive environment in which to improve mathematical abilities. The urgent need for an MMOG that combines the attraction of gaming with specific strategies to support students in elementary school with dyscalculia in their mathematical journey is made clear by the present lack of educational materials specifically designed for these students.

Objective and Scope

There are three objectives that need to be achieved. The objectives are as follows:

To identify appropriate game mechanics and elements that are suitable for applying word problem-solving strategies to enhance subtraction mathematics word problem skills.

To develop a platformer game using the appropriate game mechanics in an MMOG game engine that could help primary school students with dyscalculia.

To evaluate the effectiveness of the platformer game in helping students with dyscalculia to improve word problem skills in Mathematics. (using sus analysis and pre- and post-test).

The Minus Master scope is to create a 3D platformer game that will help children with dyscalculia and other age groups (8 to 9) become better at subtraction operations. Two separate stages will be included in the Unity-created game: the first will focus on gathering and applying subtraction symbols, while the second will provide word

questions and elementary arithmetic problems for players to answer. The principal aim of Minus Master is to offer a captivating and interactive instructional encounter that blends informative material with delightful games, therefore augmenting children's understanding and confidence in subtraction.

LITERATURE REVIEW

Dyscalculia

One type of learning impairment that affects a person's comprehension and manipulation of numbers is dyscalculia. Although dyslexia affects reading, dyscalculia impairs mathematical ability. Despite this, the two conditions are frequently compared. Dyscalculia is a major educational difficulty since, according to research, it affects around 3-6% of the population [1]. The long-term educational and psychological effects of this illness might include difficulty with fundamental arithmetic, number awareness, and mathematical thinking.

Studies on the brain and nervous system have revealed a connection between dyscalculia and abnormal brain development in regions linked to numerical processing. The intraparietal sulcus, a part of the brain essential for numerical cognition, has decreased activity in people with dyscalculia, according to functional MRI research [4]. This neurodevelopmental difference implies that the structure and function of the brain are the underlying causes of dyscalculia, impacting the way affected people understand and interpret mathematical information.

Dyscalculia can have a significant negative influence on academic performance, impacting both mathematical accomplishment and general academic success. Children who are dyscalculic frequently struggle greatly with mathematical ideas, which can have a negative impact on their academic performance, self-worth, and anxiety levels [5]. These difficulties highlight the importance of focused interventions to help impacted students and lessen the long-term consequences on their education.

Responsive teaching techniques and individualised training are common components of traditional educational therapies for dyscalculia. Research, however, shows not all students may benefit equally from these strategies. For example, drill-and-practice methods are often the emphasis of standard therapies, which may not address the main cognitive problems linked to dyscalculia [6]. This restriction emphasises the need for more creative and interesting methods to help these children.

A potentially useful tool for treating dyscalculia is technology. The unique demands of students with dyscalculia can be met by means of interactive and adaptable learning experiences provided by digital learning platforms and educational games. Research has shown that the use of technology in interventions might enhance skills in mathematics by offering specific guidance and engaging educational opportunities [7]. These resources provide fresh chances to improve dyscalculic children’s learning achievements.

Students with learning disabilities, such as dyscalculia, have found that game-based learning is very beneficial for keeping their attention. A stimulating and dynamic environment that promotes skill development may be created through game-based learning by integrating game elements into instructional materials. Research suggests that by making learning more fun and approachable, games created with educational concepts might enhance arithmetic comprehension and performance [8].

The following research must concentrate on improving game-based learning strategies and evaluating their long-term effectiveness in helping dyscalculic children. Studies should also look at how various teaching techniques and game mechanics might be improved to meet the various demands of these learners. Developing powerful therapies for dyscalculia will need ongoing research into the relationship of technology, cognitive science, and educational methods [9].

Game-Based Learning

The capacity of game-based learning (GBL) to immerse students in an engaging and entertaining learning environment has garnered significant attention. By fusing gaming dynamics with instructional content, GBL gives students challenges, prizes, and instant feedback—all of which increase motivation and cognitive

engagement [10]. Compared to students who rely on traditional learning techniques, research suggests that students who participate in GBL are more likely to retain material and acquire problem-solving abilities [11].

The ability of game-based learning to raise student motivation is one of its main advantages. Through objectives, difficulties, and prizes, games offer an intrinsic incentive that pushes students to interact fully with the material. Research indicates that GBL cultivates a feeling of accomplishment and contentment, perhaps mitigating anxiety associated with challenging courses like mathematics [12]. This section of GBL is especially helpful for students with learning difficulties because it provides a supportive, stress-free setting in which they may practice critical skills.

Game-based learning has been shown to be very useful in the context of mathematics education for practising fundamental arithmetic abilities, such as subtraction. Students may practice arithmetic problems in a dynamic environment with interactive games, where they can learn from mistakes and modify their techniques with rapid feedback. Studies show that students who utilise GBL in math have better computational abilities and are more eager to interact with mathematical ideas [13]. Students with dyscalculia, who frequently need more interesting and repetitive practice to understand arithmetic ideas, might benefit most from this method.

One essential component of contemporary game-based learning systems is adaptive learning. Adaptive GBL systems modify the learning activities' level of difficulty and pace according to each student's performance. This enables students to receive individualised education while learning at their own pace. According to research, adaptive GBL improves learning outcomes by providing customised experiences that are matched to each learner's personal requirements, particularly for those who have difficulty with topics like mathematics [13]. Teachers may guarantee that every student's educational path is optimised for success by integrating adaptive elements into educational games.

There are three ways that exist in augmented reality (AR) which can change online learning. Students will feel immersed and better able to retain the material when you initially help to create a warm and stimulating environment. Its ability to facilitate the innovative, lively, and captivating sharing of diverse knowledge and data is its second advantage. Thirdly, it encourages movement during a period of self-exclusion [8].

Academic development is not the only long-term advantage of game-based learning. Research indicates that GBL can enhance cognitive growth by promoting critical thinking, problem-solving, and decision-making abilities [14]. Furthermore, when applied in group settings, game-based learning encourages cooperation and social interaction, which raises its educational worth even more. GBL is a promising method for teaching basic concepts like subtraction to young learners and individuals with learning difficulties because of these long-term advantages.

Subtractions Skills

Basic mathematical operations like subtraction form the foundation for more complex ideas like division and algebra. It is essential for the development of general numerical competency and problem-solving skills that subtraction be mastered at a young age. Studies indicate that children who have trouble with fundamental arithmetic, particularly subtraction, are more likely to encounter challenges while studying mathematics later [15]. A solid mathematical foundation must be ensured by early treatments that focus on subtraction abilities.

Understanding subtraction is difficult for many children, especially those with learning disabilities like dyscalculia. The idea of number magnitude, the borrowing and carrying procedure in multi-digit subtraction, and the abstract character of subtraction itself are frequently the root causes of these problems [16]. Alternative solutions are necessary to help students who struggle with these ideas since traditional teaching approaches may not be sufficient in addressing these cognitive difficulties.

A useful method for teaching mathematical topics, including subtraction, is game-based learning. Students may learn subtraction in a fun, low-pressure setting by incorporating subtraction problems into interactive and entertaining games. Through increased motivation and decreased fear, studies have shown that game-based learning can enhance arithmetic abilities, especially for children who have trouble with traditional learning

approaches [13]. Children that struggle with math may benefit more from this technique, since they may find more engaging and interactive learning materials.

Learning environments that are adaptable to the individual requirements of each student have been made possible by recent advancements in educational technology. These platforms are especially useful for teaching subtraction because they enable ongoing evaluation and modification of the degree of difficulty in accordance with the development of the learner. According to research, adaptive learning systems that provide tailored help and feedback can greatly increase a user's skill with subtraction [16]. Such adaptive components can be added to games to increase their instructional value.

3D MMOG Platforms

The creation of 3D massively multiplayer online games (MMOGs) has completely changed the gaming business by allowing thousands of users to engage at once in expansive, immersive landscapes. These platforms generate dynamic virtual worlds by fusing intricate network infrastructures with rich 3D visuals [17]. The growth of cloud computing and improvements in graphics processing units (GPUs) have improved the scalability and visual fidelity of massively multiplayer online games (MMOGs) throughout time, making them a desirable medium for both leisure and education [17].

MMOGs have the potential to be educational tools since they allow users to work together to solve problems in a virtual environment. Research has indicated that massively multiplayer online games (MMOGs) can enhance critical thinking, social skills, and information retention by promoting collaboration and interaction [18]. These platforms provide chances to include scenarios for solving problems that resemble real-world problems in the context of mathematics, enabling students to use their knowledge in interesting and useful ways. Peer learning, which may be especially beneficial for children who struggle with traditional classroom-based education, is supported by the collaborative nature of massively multiplayer online games.

MMOGs benefit from the usage of 3D settings in educational games, which improves cognitive development and spatial awareness. According to research, using and navigating 3D environments forces users to comprehend intricate visual and spatial information, which can enhance their memory and problem-solving skills [19]. These advantages are especially pertinent to educational MMOGs, including those that emphasise mathematical abilities, as they provide students with a more tangible and interesting method to understand abstract ideas like subtraction.

The capacity of 3D MMOG platforms to produce immersive experiences that encourage high levels of participation is one of its main advantages. Players can immerse themselves fully in the activities of a 3D virtual environment, which frequently improves attention and tenacity in finishing tasks. This immersive aspect is essential for instructional games like Minus Master because it can lessen math-related anxiety and promote consistent subtraction task participation. Learning may be made more interesting and less scary for students by utilising the immersive capability of 3D settings in educational massively multiplayer online games.

Intersection of Dyscalculia, Subtraction Skills, and Game-Based Learning

Children with dyscalculia, a particular type of learning disability that affects the development of arithmetic abilities, have a difficult time learning simple mathematical operations like subtraction. Subtraction exercises are particularly difficult for students with dyscalculia because they frequently suffer with number sense, recall for arithmetic concepts, and the ability to handle numbers mentally [1]. These issues are typically not addressed by traditional teaching approaches, which leaves students frustrated and with less confidence in their arithmetic abilities. Innovative strategies that address each dyscalculic student's specific learning requirements are crucial for providing them with the help they need.

Gaining proficiency in subtraction is essential for overall math competency since it is a fundamental operation that supports more complicated mathematical ideas. Subtraction can be particularly difficult for dyscalculic kids as they have trouble comprehending inverse operations and sequential procedures [16]. Studies have indicated that for kids with dyscalculia to truly grasp subtraction, focused, repeating practice is necessary [20]. This offers

a significant chance for game-based learning, which enables ongoing, interactive practice in a relaxed setting that can enhance conceptual comprehension and recall.

Promisingly, game-based learning (GBL) can help children with dyscalculia overcome their difficulties, especially when it comes to mastering subtraction. Research has indicated that Game-Based Learning (GBL) can foster a more captivating, participatory, and less daunting learning atmosphere, particularly for children who struggle with arithmetic anxiety [13]. Educational games may help students learn difficult concepts like subtraction by breaking them down into smaller, more manageable activities. They can also provide quick feedback and prizes, which motivate students to keep trying. An example of an attempt to incorporate games into education, reported in a study by [21], demonstrates a positive attitude to game-based learning (GBL). Similarly, a study by [22] demonstrated that students who engaged in GBL through Augmented Reality (AR) achieved significantly higher academic performance compared to those who learned without GBL. For dyscalculic learners who gain from interactive learning and visual assistance, this method works very well.

The combination of game-based learning with certain arithmetic skills, like subtraction, offers a customised strategy for managing dyscalculia. GBL can help students build procedural fluency in subtraction as well as conceptual comprehension by providing them with an immersive, interactive platform that meets their learning demands [23]. Repetition, visual reinforcement, and adaptive learning are all included in games that might help dyscalculic kids become more confident and proficient subtraction operators. This convergence of dyscalculia and GBL offers a singular chance to reconsider subtraction instruction and make it more approachable for students who have trouble with conventional approaches.

Integration of Cognitive Learning Theory and Constructive Learning Principles to Game-Based Learning

Cognitive learning theory focuses on the mental processes that occur during learning, including attention, perception, memory, and problem-solving, rather than just memorising facts [24]. According to Anderson [25], learning involves the active acquisition and organisation of knowledge within a learner's cognitive structure. Similarly, Sweller's Cognitive Load Theory emphasises the importance of designing learning materials that effectively manage working memory to prevent overload and enhance understanding [26]. In the context of game-based learning, cognitive theory supports the use of interactive activities that stimulate thinking and reinforce memory through repeated engagement [27], [28]. With Minus Master built on cognitive principles, immediate feedback, visual stimulus, and progressive difficulty, students with or without dyscalculia are able to enhance arithmetic knowledge and memory through organized cognitive activity.

In the case of constructivist learning theory, it is connected to the construct knowledge of the learners as a result of experiences and reflection as opposed to being presented with information passively [29], [30], [31]. Meaning learners will be active and will be able to adjust their knowledge by assimilation and accommodation by taking part in experience and reflection about the experience. In mathematics learning, constructivist approaches promote active discovery, problem-solving, and hands-on activities that enable students to build their own conceptual understanding. This can be confirmed in [30], where the author mentions that the constructivist method in arithmetic and mathematics focuses on the students building knowledge by their efforts instead of merely receiving facts [32]. Game-based environments, such as Minus Master, exemplify constructivist principles by allowing learners to explore mathematical operations, make mistakes, and receive feedback in an engaging and supportive setting. This experience process results in independence, enthusiasm, and better understanding, especially with learners with dyscalculia as they prefer to learn visually and interactively and at their own pace.

METHODOLOGY

This chapter explains the methodology used for the development of Minus Master following the Analysis, Design, Development, Implementation, Evaluation (ADDIE) model, which consists of five stages: analysis, design, development, implementation, and evaluation. Each phase outlines the process of creating an effective game-based learning tool aimed at improving subtraction skills, particularly for children with dyscalculia. The chapter also includes the software and hardware requirements necessary for the project's success.

Analysis

During the analytical stage, the goal was to comprehend the learning challenges that children with dyscalculia encounter, particularly in relation to subtraction. The fundamental difficulties were found via investigation and data gathering, and they included problems with worry, insufficient self-assurance, and trouble grasping simple subtraction ideas. This stage proved that students needed a game-based learning platform that could give them a fun, stress-free environment to practice subtraction. The goals of Minus Master were outlined, including enhancing mathematical abilities and lowering math-related anxiety. The project's predicted results and completion date were also made explicit.

Design

The original thoughts were developed into a detailed game strategy throughout the design process. Minus Master was developed in the 3D platformer genre, which is perfect for involving younger players in interactive learning. Sketches were used to develop the concept and design of visual aspects, including game characters, environments, and symbols. Digital technologies like Adobe Illustrator were then used to polish the final designs. Young players may simply manage the game because of the thoughtfully created basic and easy user interface. In order to keep the game visually appealing and playable for children with learning disabilities, the design phase also involved developing game mechanisms for gathering subtraction symbols and resolving arithmetic issues.

Development

The designs were realised throughout the development period with the use of C# programming and Unity (version 2022.3 LTS). To guarantee fluid gameplay, the essential game mechanics, such as gathering subtraction symbols and avoiding plus symbols in the first level, were programmed. Players had to complete word problems using subtraction in the second level, and the adjustable difficulty made sure that each player's experience was tailored to their level of understanding. To produce realistic character movements and increase interest, animations were developed using Unity's physics engine. Continuous testing and improvement were made possible by the iterative development method, which ensured that every element worked as intended and complemented the game's instructional objectives.

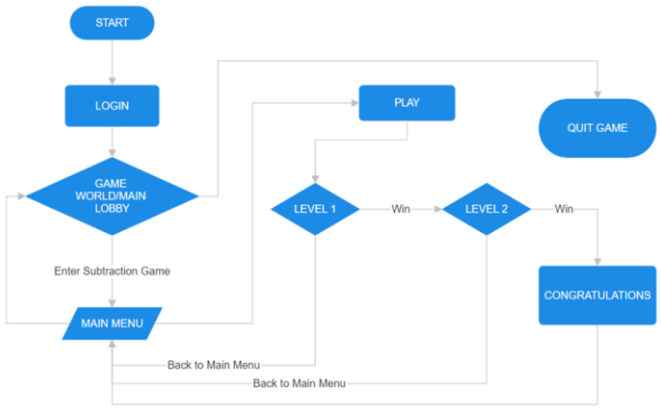


Fig. 1. Game flowchart

In controlling the real-time multiplayer session, the Atavism server is used. The Atavism server does player logins, keeps the game running in real time, and allows players to talk with each other, where each student needs to log in to the server to allow the server to recognise the unique ID of each player. The server also allows the game to store user data, game progress, and performance metrics in a secure and efficient database. There are two levels created in the game, which require students to complete the first level before they can move to the next level.

The game features two levels of mechanics that incorporate platformer elements within a colourful, animated environment, including activities such as racing, jumping, and puzzle-solving. Level 1 is designed to be simpler and aims to help students with dyscalculia differentiate between addition and subtraction symbols. Recognising

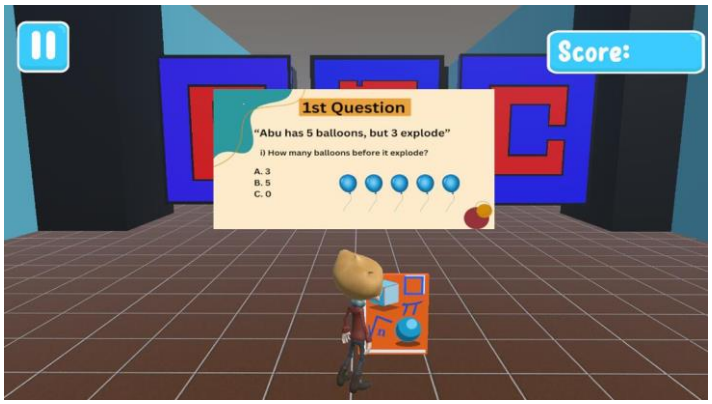
the correct symbol before answering questions is crucial; without this understanding, it becomes impossible for the children to respond accurately

At Level 2, the level will assist dyscalculia children in practising one-word subtraction and doubles, gradually using two-word problems so that they pay equal attention to both questions. The aim is to help them get used to the values of a, b, and c in the formula a - b = c, and they have to answer them in order to get right along to their next question. Each of the levels will have a total of 10 questions, but the major section has its first 5 questions, where each question consists of these sub-questions.

Fig. 2. Main menu screenshot

Fig. 3. Level 1 gameplay screenshot

Fig. 4. Level 2 gameplay screenshot



Implementation

To guarantee widespread accessibility, Minus Master was tested with a group of primary school pupils, both with and without dyscalculia, once it was finished developing. During the implementation phase, users' interactions with the game were observed, with a particular focus on their comprehension of the subtraction problems and level of engagement with the game. User opinions about the game's complexity, the UI, and the entire educational process were gathered. This stage made it possible to make changes in real-time, which enhanced the game's usability and made sure it accomplished its goal of teaching subtraction in an engaging and dynamic manner.

Evaluation

Based on user testing and feedback, Minus Master's overall success was evaluated throughout the assessment phase. Information was acquired about how successfully the game helped players, especially those who struggled with math, improve their subtraction abilities. Additionally, pre- and post-game surveys were used to assess the decrease of arithmetic fear. The game's ability to foster a relaxed, interesting learning environment was evaluated. The assessment phase's lessons will be used to Minus Master's next upgrades and iterations, which aim to improve the game even more and broaden its instructional application to include more difficult mathematical ideas.

To evaluate the usability and educational effectiveness of Minus Master among children, a total of 35 primary school students from School A, were selected to participate in the study. Upon completing the game, participants were asked to complete the System Usability Scale (SUS) to assess their satisfaction and the game's usability. Meanwhile, the calculation of the SUS analysis used in this study is adapted from [33]:

For each question with an odd number (Qo), the following equations are used:

$$Q^O = \sum_{i=1,3,5,7,9} X - 1 \qquad (1)$$

Next, for each question with an even number (Qe), the subsequent equations are used:

$$Q^e = \sum_{i=2,4,6,8,10} 5 - X \qquad (2)$$

X = value from questionnaire,

After that, the SUS score for every response is calculated using the following specific equation:

$$S = (Q^o - Q^e) * 2.5 \qquad (3)$$

Finally, to calculate the overall SUS score based on all responses, we use the following equation:

$$= \frac{\sum i - 1\ (\sum i = 1,3,5,7,9^{\,X-1}) + (\sum i = 2,4,6,8,10^{\,5-X}) * 2.5}{n} \qquad (4)$$

Additionally, pre-test and post-test assessments were administered before and after the gameplay session to measure any improvements in students' academic performance, thereby determining the game's impact on their learning outcomes.

ANALYSIS AND DISCUSSION

To evaluate the game's usability among students, the System Usability Scale (SUS) was administered using a standardized 10-item Likert-scale questionnaire. Participants responded to each item on a five-point scale ranging from 'Strongly Disagree' to 'Strongly Agree', providing a quantifiable measure of their perceptions regarding the system's effectiveness, efficiency, and overall satisfaction [34], [35].

Table I. SUS overall performance

No.	SUS question	Minimum Like-scale value	Maximum Like-scale value	Mean	SD
1	I think I want to use this game often	3	5	4.11	0.676
2	I found this a bit complex to play	1	5	1.91	1.147
3	I think this game is easy to use	1	5	3.94	1.187
4	I think that I would need the support of a technical person to be able to play this game	1	5	2.66	1.305
5	I found the in-game features to be well put together	1	5	4.17	0.923
6	I think a lot of things are not consistent in this game	1	5	3.40	1.376
7	I think people will learn to use this game very quickly	1	5	4.23	1.060
8	I found the game very cumbersome to be use	1	5	1.97	1.124
9	I feel very confident using this game	2	5	4.09	1.067
10	I need to learn a lot of things before I can play this game	1	5	2.66	1.552

The SUS questionnaire consists of ten items, which can be categorised into two groups: odd-numbered and even-numbered items. The odd-numbered items (Questions 1, 3, 5, 7, and 9) are designed to capture positive user perceptions regarding the system's usability, while the even-numbered items (Questions 2, 4, 6, 8, and 10) assess potential negative aspects of the user experience. This balanced structure allows for a comprehensive evaluation of both strengths and weaknesses in the system's usability from the participants' perspective.

Among the odd-numbered group, Question 7 ('I think people will learn to use this game quickly') received the highest mean score of 4.24. This was followed by Question 5 ('I found the in-game features to be well put together') with a mean score of 4.17, and Question 1 ('I think I want to use this game often') with a mean score of 4.11. Consequently, the children feel that the game is simple and the action inside is steady as they play the game. In short, it led the children to play the game again and again after their initial experience. For Question 7, which assesses the children's confidence while using the game, the mean score was 4.09. Meanwhile, Question 3 ("I think this game is easy to use") recorded a mean score of 3.94.

Next, for the even-numbered group, Question 6 had the highest mean score with 3.40, so there are some children who feel the game is not very consistent. However, the percentages are still lower compared to Question 7, which indicates more children are confident when playing the game. Question 4 ("I think that I would need the support of a technical person to be able to play this game") and Question 10 ("I need to learn a lot of things before I can play this game") record the second highest mean score, with both questions get 2.66 for the mean score. The scores for Question 2 ("I found this a bit complex to play") and Question 8 ("I found the game very cumbersome to use") were both under 2.00. These are good signs that indicate mean that the game is designed in a way that is easy for children to play.

The final SUS score collected from the 35 respondents is 69.86, which is graded as C according to the general grading scale of SUS scores [36]. This classification suggests that the system is usable on average, though not yet of very high quality. That means, although most children consider the game to be useful and reliable, there are still several areas in which it can be improved to make things better for users. This score indicates that the game created is usable enough, yet there is plenty of room for further refinements.

Furthermore, to evaluate whether the game can enhance students' learning and understanding of the simple subtraction topic, a pre-test and post-test were administered by using the Google Forms platform. The maximum score for the online test is 11, and both sets of questions are similar. Figures 5 and 6 below present the pre-test and post-test results.

Fig. 5. Pre-test score

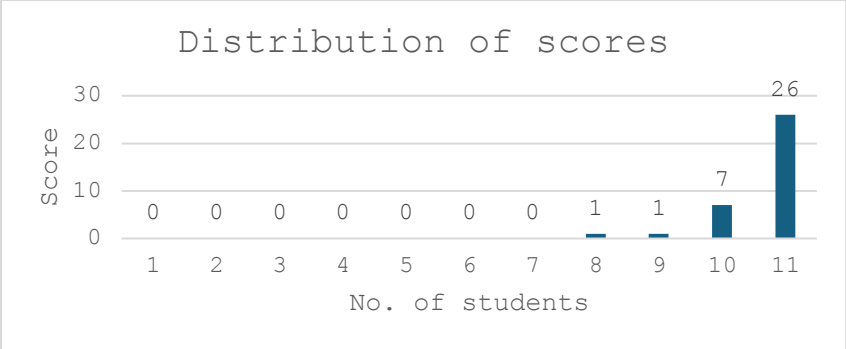
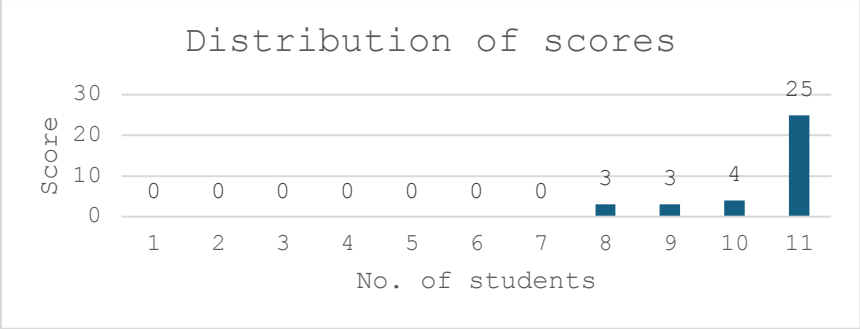


Fig. 6. Post-test score



Although there was a slight decline in scores between the two tests, the scores are still acceptable, with 25 students getting a maximum score of 11, which is 25 students or 71.43%, followed by 4 students (11.43%) managing to score 10. The rest of the students are in the category of having scores of 9 and 8, each of which includes 3 (8.57%) students. Most of the student feedback was overwhelmingly positive, and overall, children found the game engaging and effective in helping them improve their subtraction skills.

CONCLUSION

Minus Master uses the captivating features of a three-dimensional platformer game to effectively solve the difficulties dyscalculic kids have learning subtraction. Students may practice and develop their subtraction abilities in a low-pressure atmosphere in this exciting game thanks to its clever design and interesting gameplay. To suit the demands of its intended audience, learning is made both interesting and successful through the integration of game mechanics and educational psychology concepts.

Positive user testing response shows that students find Minus Master to be well-received, with considerable increases in engagement and subtraction confidence. The game is still quite helpful in improving mathematical abilities overall, despite a modest decline in performance scores over time. Multimedia specialists have confirmed the game's design, praising its visually appealing and user-friendly interface, which further supports the game's effectiveness as an instructional tool.

The combined feedback from both System Usability Score (SUS) and students' pre- and post-test supports the conclusion that Minus Master is an effective tool for enhancing students' subtraction skills through interactive and engaging gameplay. This positive evaluation fulfils Objective 3, which aims to assess the effectiveness of game-based learning in improving mathematical abilities, particularly for children with dyscalculia.

As this study only evaluates the student performance once, future research should include long-term follow-up assessments to evaluate the extent of knowledge retention and skill transfer beyond the immediate gameplay experience. Such assessments would provide deeper insights into how the learning outcomes achieved through Minus Master are maintained and applied in real-world mathematical contexts. Moreover, it may be possible to implement the elements of multiplayer collaboration and social learning in the future versions of the game as a part of the Massively Multiplayer Online Game (MMOG). Such a method would promote peer interaction, collaborative problem-solving, and shared learning experiences, which would be in line with the principles of social constructivist philosophy that emphasizes collaboration as an essential tool to improve comprehension and motivation.

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