EnlightenDS: Advanced Technologies for Skill Enhancement and Talent Recognition in Children with Down Syndrome

Project Proposal Report

Project ID: 24-25J-228

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DECLARATION

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We declare that this is our own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The supervisor/s should certify the proposal report with the following declaration. The above candidate is carrying out research for the undergraduate dissertation under my supervision.

Signature of the supervisor
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Figure 0.1 Declaration

ABSTRACT

This study aims to address the educational challenges faced by children with down syndrome and identify how learning technology may enhance learning in children with down syndrome, who have key issues that traditional methods do not adequately address. Down syndrome is a genetic disorder, and they have multiple physical and cognitive disabilities. Their IQ is usually 50, which is a big fall from the average person. They normally suffer from speech and language impairments, working memory problems, attention span, and problem-solving difficulties. These cognitive impairments make standard learning procedures not enough for these individuals and the need of special learning solutions. This research investigates the development of an integrated education system known as, ‘’EnlightenDS’’. The presented study aims to design a system that includes a cognitive assessment, pronunciation training, adaptive mathematics quizzes, and interest-finding features to create positive learning experiences of children who have down syndrome. The mathematical skill development system first involves an initial assessment in the form of a pre-test and then involves training using well-documented methodologies that include the kumon, stern, and numicon methods. Also, the system tracks the child's performance and prepares progress reports for the parents. These reports offer insights into the child's areas of strength and those needing improvement. The study concludes that the implementation of such a system, as “EnlightenDS’’, may effectively improve the learning process and leave a positive impact on the learning achievement of children with down syndrome while at the same time making the learning process enjoyable

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LIST OF ABBREVIATIONS

DS	Down Syndrome
IQ	Intelligence quotient
TG	Training group
CG	Control group
WS	Williams syndrome
TD	Typically developing
ANCOVA	Analysis of covariance

1. INTRODUCTION

Down Syndrome is a genetic disorder that occurs when there is an extra copy of chromosome 21 [1]. This chromosomal defect occurs in about 1 out of every 700 live births worldwide and leads to a range of physical appearances as well as intellectual dissimilarities [1]. People with DS always have a particular appearance like a flat facial profile, an up-slanting eye, and a single deep crease in the center of the palm [2]. The cognitive impairments in DS can vary in severity, ranging from mild to moderate. The average IQ for those with DS is approximately 50, which is way a lot lower than the average IQ of the overall population [3].

Academically, children with DS experience numerous difficulties. These can be speech and language delay, reduced working memory capacity, and problems as regard to focus and attention [4]. Children with receptive and expressive language disorder may have difficulties in comprehending mathematical language and written word problems; they may also have difficulties in formulating numbers and word problems into numerical forms and vice versa, as well as being less effective in recalling mathematical algorithms, number facts, and problem-solving skills. Also, hyperactive children prefer shorter durations of attention and cannot easily concentrate on activities involving attentive mental effort such as solving math problems [5].

It is clear that children with DS, as has also been observed in the case of the two children mentioned in the paper, develop math skills much slower than a typically developing child. Such children mostly have difficulties in mastering number sense as well as number operations including counting, addition, subtraction, multiplication, and division. For example, number identification, and counting prepare students for higher-level problems in arithmetic. Socialization and numeral competence may also be impaired in children with DS and this as a result prevents them from having acceptable arithmetical skills whereby even simple number operations may pose a significant challenge to them [6].

In addition, basic arithmetic skills fail in children with DS because of cognitive problems that they experience. Learning and memorizing mathematical outcomes, for example, addition or multiplication involves a lot of number drills, amid which such children may be overwhelmed [7]. Moreover, applying the learned theory to recent problems presupposes thinking abilities, which are in turn a part of higher mental processes and, as it was mentioned earlier, are not developed in the students with DS. In approaching problems, they may not be able to move from one problem to another easily or subdivide a problem into smaller and easier-to-solve problems [8].

When it comes to analytical skill development, at initial stages of development, children with DS may concentrate on concrete problem-solving tasks and easy pattern recognitions. Slower processing speed and working memory difficulties usually limit their ability to analyze information. Teaching techniques like hands-on instruction, pictures or diagrams, and repeating can enhance the acquisition of such competencies.

Analytical Skills in Middle Childhood: As individuals grow older (ages 8-11) the skill progressions include more complex analytical tasks e.g., understanding cause and effect relationships; multi-step problem solving etc. Nevertheless, some difficulties in abstract thinking and generalization of concepts might persist. Effective teaching often requires dividing tasks into smaller manageable steps and explaining abstract ideas using specific examples [9].

At ages 12-15 (adolescence), children with DS may gain superior skills in reasoning that permit them to apply logic and formulate solutions. However, these children will still need someone to help them surmount hindrances like thinking abstractly and completing higher cognitive tasks. Personalized learning tools and adaptive quizzes, customized educational interventions, can be instrumental in the acquisition of these skills through targeted practice as well as feedback [10].
Development of mental and analytical competencies among individuals aged between five to fifteen years suffering from DS is gradual but constant. Improving their learning outcome which supports cognitive development and academic growth can be achieved by considering educational approaches that cater for their specific needs and cognitive profile. Nevertheless, with adequate assistance, kids with DS can improve their mathematical skills.

1.1 Background literature

Children with DS struggle with arithmetic skills. Numerical skills in these individuals are delayed by two years compared to literacy. So, the researchers have discovered several teaching methods for counting and number recognition. All these methods are designed for DS children, and some of the child centers are already using them. But most of the people still do not have good knowledge about these methods. So, our aim for building this system is to give an innovative idea about these methods for the parents and caregivers and incorporate all these methods into our novel system [11].

There are 2 teaching methods for numeracy. They are,

1. Kumon Method
    - Approach: It requires practice through the method of repetition and slow building up of exercises in difficulty. A primary aim is to teach elementary numerical operations and basic skills at each time before progress is made to other levels. [12] [13]
    - Materials: The primary teaching aid of the Kumon method is the worksheets through which students work on their own. Unlike some other available material, these worksheets have been systematically constructed to grow in difficulty, starting with easier exercises while gradually ascending to more difficult variants. [11] [13]

- Benefits: It is effective in building a self-learning attitude and aids in solving capabilities. It also provides an opportunity for learners to advance at their own pace and this enables them to master the concepts being offered entirely. [13] [11] [12]

2. Stern and Numicon Method
    - Approach: This method involves the use of objects, and graphics to explain numbers and their properties. While teaching and learning numbers, it seeks to adopt the use of concrete objects and graphics to make the existing invisible numbers come to life. [11] [13] [12]
    - Materials: The Numicon Method incorporates distinct detachable colorful separators and numerals to solve a mathematical problem. These shapes enable a child to manipulate the number to feel concepts like addition, subtraction, value, among others.
    - Benefits: Often it is most effective for visual and tangible learners. The actual appearance of physical materials that assist in showing concepts, which might be difficult for young children or the physically challenged to understand could be developed.

These two approaches have their own merit and one can be used depending on the needs of the individual learner. The integration of both approaches would be a better way to teach numeracy as it provides an overall view.

The following are the essential principles that must be grasped to teach counting effectively to the learners. Here is an overview of the principles: [12]

- One-to-One Principle: This means each object of a certain group must be given a distinct number each time one counting is done. For instance, if you count five apples, each apple must be attributed one number which means that, none of the apples should be left out by the counters or have numbers repeated on them. [12]
- Stable-Order Principle: They must be chanted in the correct sequence (for instance 1, 2, 3, or 4 and 5). This principle assists children in making a realization that numbers are a particular sequence. [12]
- Cardinal Principle: The last number counted gives the total number of items; this gives the cardinality of the set. For instance, when counting five blocks and using the word ‘five’ to refer to the last item on the count, one learned that there were five blocks in total. [12]
- Order Irrelevance Principle: Whether you count objects along the horizontal plane from left to right or right to left, or down the vertical plane from top to bottom, or from bottom to top… the sum is the sum. These principles highlight the fact that the counting process is independent of the sequence of the count. [12]
- Abstraction Principle: People can count not only physical objects, but also sounds, events or something that is beyond people’s imagination. This principle maintains that counting is a very versatile skill that can be applied in a broad context. [12]

The integration of such principles in the counting activity helps develop a structural base of number knowledge and enhances the learning of higher-order mathematics. Of this whole concept of numbering, our number is a base 10, hence the number ten is important. And as for that there is an approach called rainbow facts to number 10.” Rainbow Facts” is a method appropriate for teaching students in order that they develop and memorize the number combinations that are equal to 10. This is because colors and patterns have a way of making information as learnt through the combos easier to remember. [12]

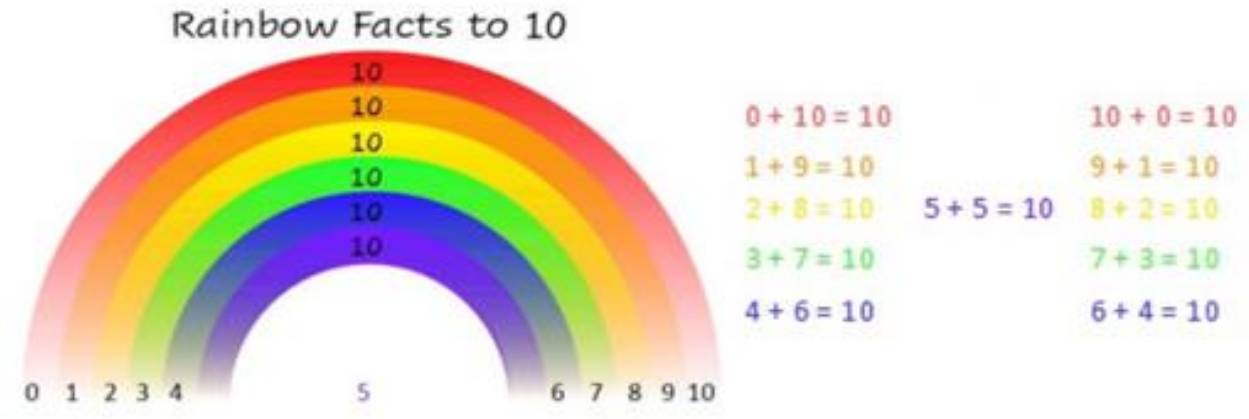

Figure 1.1 Rainbow facts to number 10 method [12]

Source: https://www.dsrf.org/resources/learn-at-home/learn-at-home-activities-for-math/

All these methods are designed for DS children. Because of that using all these teaching methods can be effectively helping to enhance the mathematical skills of the children with DS.

In the background study, research with the title ‘‘Training basic numerical skills in children with DS using the computerized game ‘The Number Race’,’ analyzed the impact of an intervention on children with DS. [14] The study involved two groups: a training group (TG) that used the “The Number Race” to increase the identified numerical skills, and a control group (CG) that used software designed for the development of literacy. The main aim of the study was to assess the effects of numerical training; secondary they looked at the possibility of literacy gains from the reading software. Both groups were assessed on their numerical and reading skills at three intervals: The assessments were conducted with three groups of subjects before and after the training and three months later: pre-test, post-test, and follow-up test. The researchers expected the TG to exhibit significant improvements in numerical skills from pre-test to post-test and at follow-up as well. [14]

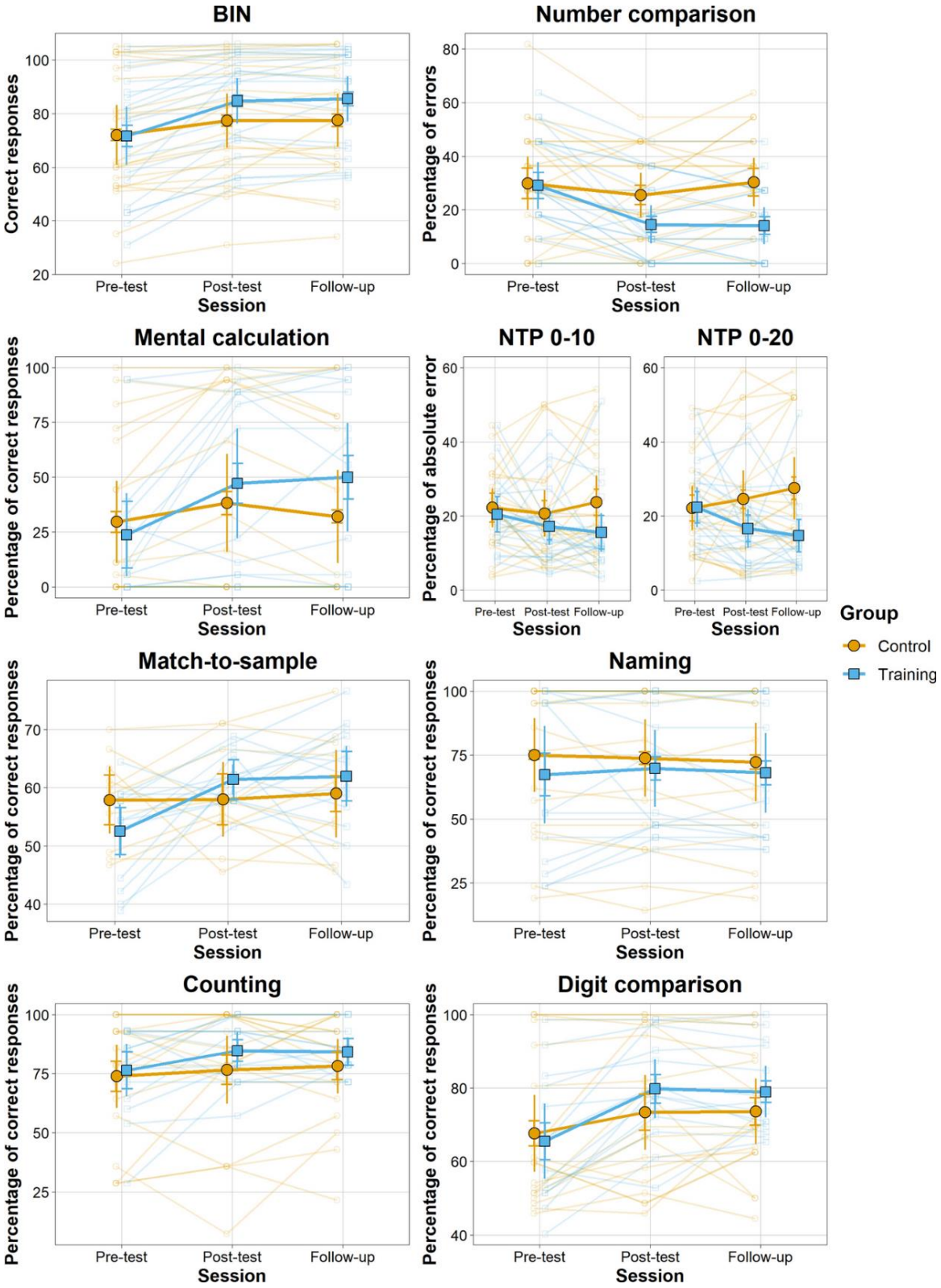

Figure 1.2 Results of the research called "Training basic numerical skills in children with Down syndrome using the computerized game 'The Number Race' [14]

Source: https://www.nature.com/articles/s41598-020-78801-5

The review of the literature has revealed that Michigan's children have learned better when taught through multiple tasks that affect more than one sense at a go. Introducing teaching procedures such as the use of graphic and visual materials, use of objects, and use of auditory instructions can assist to strengthen mathematical understanding and also assist the children with DS in learning [15]. Further, technologies that have personalized adaptive learning where the level of difficulty of questions and kind of knowledge delivery is based on the performance of the learner can facilitate help these children to foster the necessary mathematical skills [16].

Proposed system:

Special learning systems are promising for enhancement of child's quantitative performance with DS by achieving higher quality than white traditional instruction by customizing instruction for each student. The proposed system expects to take advantage of the adaptive quizzes to make learning as fun as possible. The system can, thus, in the first instance, rely on the performance data of the users in terms of age and difficulty levels in tackling arithmetic problems to determine the child's ability and direct him or her to problems that they would find challenging enough.

Initially, the users will start with questions from the beginners' pool in order to gauge the amount of knowledge that the user possesses. As the child answers questions, the system dynamically adjusts the difficulty based on their performance: The right answers eventually take the quiz-takers to more subjective questions, and the wrong ones take them to questions like or one level below the incorrect response. This kind of approach provides a way by which the child is constantly engaged but on a level that is slightly difficult enough to enable him or her to learn progressively. The thing is that the passage to the next level of difficulty depends upon the rule-based system, for example, going to the next level after achieving more than 15 correct answers. As the programmed number of questions at a particular level of difficulty is reached the system then produces a quiz which consists of random or slightly altered questions from the set. This quiz is designed to check the child's understanding of the concepts taught with the help of time taken on each question, and the number of correct and wrong answers. In respect to the evaluations, the score of the child depends on the number of answers given successfully; if the defined level of pass mark is achieved, the child proceeds to the next level of difficulty. If the score is less than this number, the child stays at this level until he/she shows sufficient mastery.

To complement the learning process, the system builds in educational animations made with such applications as "Animaker" or "PowToon." These animations give definitions of the concepts and where necessary show how incorrect answers should be solved in an easy-to-understand manner. As implemented with these clips in the learning process, the system seeks to enhance the teaching and learning process, making it even more efficient for children with DS.
Further, there is an educational report for parents, which lists the child's performance at each level: time spent, scores, and number of correct and incorrect answers. This report consists of data

profiles of the child's progress over a period, the capabilities that have been developed, and the capabilities that require enhancement. This way parents can monitor their children and know the progress their child is making in school, using them to support the child as they go through the learning process.

In general, the adaptive learning system plans to meet the education needs of children with DS to help children enjoyably improve on mathematical education. Incorporating the adaptive quizzes, the educational animations and the performance tracking the system seeks to provide students with a rich and engaging learning environment that would enable the child to increase his/her achievement level in mathematics in a seamless manner that would be supportive of his/her learning process.

1.2 Research Gap

Research A: The present research aims to evaluate the effects of the computerized game "The Number Race" on enhancing the specific numerical competencies of children with DS. All the children with DS showed weaknesses in numerical operations which in a way impact daily numeracy and mathematics. The study had 61 participants and included children with DS – the TG consisted of 30 children playing 'The Number Race'; the CG consisted of 31 children using software for reading. The training program was 10 weeks with two training sessions a week, each 20 – 30 minutes in duration, and interventions made before, after, and 3 months after training. The results established that even as both groups began the experiment revealing comparable numerical ability and post-training increase, the TG revealed a significant ontological increase in particular numerical abilities and proficiency in mental calculations which were sustained and which the CG whose general reading ability experience a notable enhancement and a minor numerical improvement only. It is for this reason that at the end of the study it was found that "The Number Race" enhances specific numerical abilities in children with DS especially in tasks that involve number transformation. Nevertheless, several limitations applied to the study; no control group using traditional teaching methods; the training time may not have been sufficient; participants' skills varied greatly; the game did not adapt; some participant assignments were not random; assessors were not blinded; and no measures of application in real life were used. These limitations recommend the necessity of further investigations about the effective training techniques for children with DS and about the parameters defining optimum training time amount, flexibility, and practicability of the learned skills. Thus, this work has some methodological limitations, yet it confirms the promise of computerized games in special education and the benefits of developing the numerical competency of children with DS [14].

Research B: The findings of this research were organized according to the purpose of evaluating the current state of knowledge about which types of math interventions have been used and found to be effective for children and teens with DS and whether the intervention considers or addresses

DS-related behaviors. Nine empirical studies from 1989 to 2012 were analyzed and all of them were aimed at general mathematics learning and especially at such skills as counting and recognition of numbers. In most cases, these studies were found to yield positive outcomes in favor of the ability of intervention to enhance basic mathematics. Still, none of the studies can be considered methodologically well designed, thus, having low research quality, and none provided on-purpose differentiation to address behavioral features of DS. The results are like the other reviews of the people with DS, which were focused on the applied interventions, which also revealed that the interventions had some positive effects, but the quality of the research was poor. The review also pointed out that because of the insufficient sample of qualified research, it is difficult to establish which mathematical intervention for children with DS is the most efficient. It also advocated for more comprehensive studies to provide a resolution on the efficacy of these intercessions. In accordance, the researchers should focus on the behaviors of the people with DS during the interventions in future studies. But it has not undergone vigorous testing as of this writing. Further and more comprehensive investigations are necessary to realize how specific mathematics lessons promote academic success and higher levels of self-sufficiency among children and adolescents with DS [17].

Research C: This paper reviews some of the difficulties that students with DS have in learning early numbers that form the basis of all mathematics. Problems at this level are related to quantity, numeral, counting, and comparing quantities problems. Counting is another area in which children with DS are said to display weaknesses in stable order, cardinality, and working memory. These fundamental issues continue to other emphases of mathematical learning including number facts, time, money, rationally, and problem-solving. There are few studies on mathematics teaching and learning in children with DS, and most of them address early numerical skills and are methodologically unsound. The review found eight studies comparing the mathematics achievement of children with DS to that of other children, but sample sizes were small, measures used were inconsistent and children were not always matched for the study. To provide a clear outlook of the DS phenotype's effects on mathematics performance, future research must employ a broader age range and higher quality of matching. Also, it can be useful to compare DS children to other groups of children with ID to determine if certain difficulties are specific to DS or are seen in ID children in general. Longitudinal research is needed to describe the development of mathematical skills and to find out practices that might improve education for children with DS. Recent evidence points to the fact that much of the literature may be outdated because of elevated mathematical requirements and expectations in schools and society, and therefore there is a need for high-quality current research to guide the practice [18].

Research D: In this research, 24 persons with Williams syndrome (WS) and 26 with DS, 8–51 years of age were selected for the study to evaluate their mathematical skills against 26 typically developing (TD) children of age 4–10. The pre-intervention Raven’s Colored Progressive Matrices (RCPM) score and therefore general fluid intelligence of all participants was matched. Detailed

data was provided to the parent written consent was acquired and verbal assent from the children was also gained. The tasks were not ordered, and the participants were tested individually by a researcher in a quiet room. The testing sessions were of a mean duration of one hour and the participants were allowed to take breaks midway through the test. Cross-sectional ANCOVA tests examined mathematical development in WS and DS about age and various general and specific skills. Studying developmental rate and onset of calculation, the three groups – WS, DS, and TD – did not differ if domain-general abilities were patriated, except visuospatial deficits in WS. As a result, non-symbolic and symbolic number abilities could be considered as a valid and reliable indicator of the overall performance in math across all the groups. The results imply that individuals with WS and DS develop numeracy skills throughout their lives [19].

	A	B	C	D	EnlightenDS
Creating adaptive question logic	✗	✗	✗	✗	✓
Divided questions into age range groups and difficulty levels	✓	✗	✗	✗	✓
Focus on improving basic numerical skills	✓	✓	✓	✗	✓
Educational animation integration for explanations and training	✗	✗	✗	✗	✓
Quiz creation	✗	✓	✓	✗	✓
Get overall statistics of performance	✓	✓	✓	✓	✓
Provide further development instructions for the parents by analyzing status of the child	✗	✗	✗	✗	✓
Application created	✓	✗	✗	✗	✓
Web application	✗	✗	✗	✗	✓

Table 1.1 Research gap

The current learning applications target basic skills and embrace different facets such as questions pool, quizzes, and results' subsequent assessment. However, existing research does not provide an adequate combination of adaptive learning systems that provide content according to the child's potential. Modern tools in most cases do not offer integrated educational animations for training and purposes of explaining a topic, a feedback system for parents, and a performance tracking system.

"EnlightenDS" is developed for children with DS and its features are such as the adaptive question logic, breaking the questions into ranges of ages and difficulties, working on the basic numeral competencies, educational animations, and performance monitoring. In contrast to the existing tools and studies (such as research A not using adaptive learning, and research B and C employing simple numerical methods), "EnlightenDS" is based on effective learning suggestions with child requirements. Also, this system gives comprehensive suggestions and further development advice to the parents which is observed in other methods. This way, the features included in "EnlightenDS" provide a more comprehensive educational solution when integrated into a single Web application, addressing apparent gaps between the previous approaches.

1.3 Research Problem

Cognitive development in children with DS is different from that of children with no DS because of the genetic condition of their brains. The main problem of this population is that they face difficulties connected with memory, problem-solving skills, and the processing velocity they can affect their daily life, including mathematics. Intellectual development in this population is usually delayed but progresses in the same manner as in normal children. There are developmental milestones children with DS should achieve between 5 and 15; they may attain these milestones more slowly or may need help.

- According to the research, at 5 years old children with DS are learning early aspects of cognitive development, including simple reasoning and memory. Although, like their peers they are not mentally challenged and can execute tasks and meet objectives, often their mental processing speed is not as fast as their peers, and they may also have problems with attention spans.

- At 7 to 8, children can handle more complicated information such as categorization and sequencing of information though abstract thinking remains a major issue for children at this age. [20] [21].

- Usually at 9 to 15 years old, children show better memory, attention, and problem-solving. But learning may still be retarded, and they are not able to reason like other children of their age. Cognitive difficulties that may be seen in adolescents with DS include impairment of abstract thinking and higher-order cognitive skills, this makes it difficult for

a child with DS to solve complex mathematics problems or perform highly analytic tasks [22].

So, based on this information, we have analyzed what would be the most appropriate research problem for our system. That is,

How can the use of adaptive learning technologies be effectively employed to support the development of basic math skills for children with Down syndrome given their unique numerical skill acquisition challenges?

To clarify the above research problem, we have several specific questions that include:

- Which are the most efficient adaptations used in teaching children with DS about recognition and counting numbers?

- How could adaptive learning systems be designed to bridge the two-year gap between mastery of literacy and numeracy among children with DS?

- Also, what is personalized feedback from whom when it comes to improving one-to-one correspondence, numerical order, and cardinality understanding in DS children?

- Additionally, how can adaptive learning technologies be created to gradually expose more intricate mathematical notions like simple addition and subtraction that correspond well with exceptional learning requirements among children with DS?

- Lastly, what results should we expect if we were to apply this technology to the everyday life skills of these disabled kids?

.

2 OBJECTIVES

2.1 Main Objective

The focus of this research is to develop an adaptive educational system for children with DS that supports the cognitive, linguistic, mathematical, and creative development of children with DS, aged 5-15 through personalized and adaptive educational interventions. It will integrate with custom quizzes which vary in difficulty according to the scoring and performance tracking mechanisms. And, to assess the system's effectiveness by measuring how much it helps improve mathematical skills and provide further development instructions for the parents by analyzing the status of the child.

2.2 Sub Objectives

- Create Adaptive Quiz System

  Interactive quizzes that get harder as you get better at practice level adjust the difficulty of questions to best suit the child while keeping them challenging and enhancing learning appropriate for where they are at with their skill set.

- Educational Animations for Math Concepts

  Integrate animations that demonstrate math-related one's calculations. This visual technique is effective at communicating the core mathematical ideas and processes in a way that children with DS can relate to.

- Easy to Use Interface and Tracking System

  A quick, user-friendly interface experience designed to cater to children with DS. Performance tracking and reporting. It automatically creates detailed reports on the progress, and time spent that can help inform parents or educators about how to accompany their child's learning curve.

- Feedback and Improvement

  Get input from kids, parents plus educators for a user interface in addition to presented system. The goal is to incorporate these models into a system that refines itself using quantitative data.

3 METHODOLOGY

3.1 System Architecture Diagram

3.1.1 Overall System Architecture Diagram

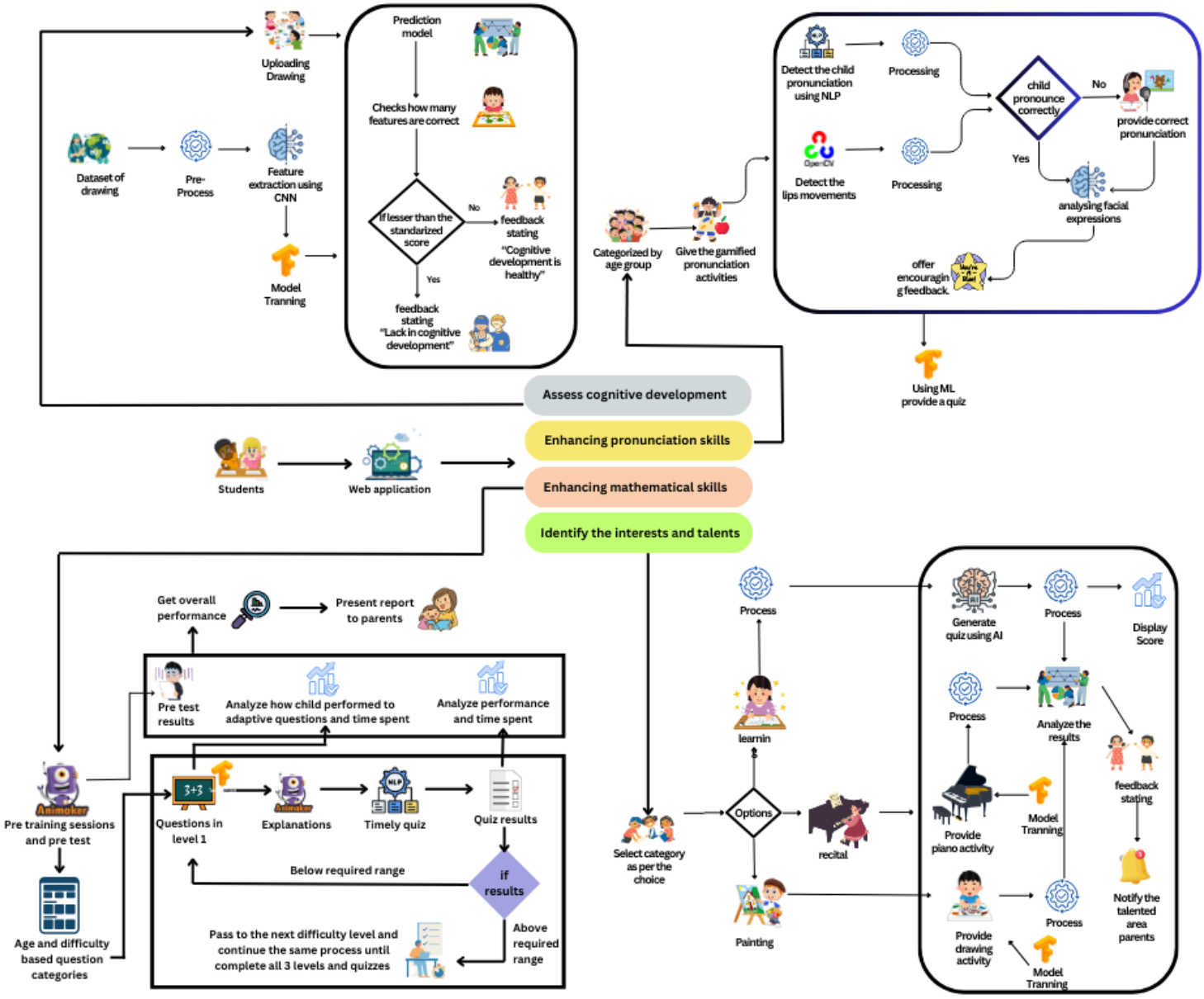

Figure 3.1 Overall system architecture diagram

The system in the figure is an educational tool for the examination and development of all aspects of the child's cognitive level, pronunciation, numeration and to identify potential talents. It works together with several modules.

The system initiates by getting data from Kaggle which is followed by data preprocessing so that it is ready for analysis. Then a model for estimating the level of cognitive advancement is built. Users can upload an image, and the system provides the user with a cognitive development score. This score is then compared against a standard score. In case the score is low, the system informs that the child's cognitive skill development is not adequate. If the score is ok, the system informs the user that the child's development is quite healthy, and no further action is needed.

The second module is the pronunciation enhancement module. This aimed at the speaking activity. Images are displayed with the correct word pronunciation and then the child must pronounce it aloud. By so doing, the system developed using OpenCV recognizes the facial movements of the child and concentrates on the mouth so that the pronunciation tasks given should be completed correctly. In the case of a child who is weak in pronunciation, the system assists them and shows the right way until the correct pronunciation is accomplished. After correct pronunciation, the system provides motivating messages regarding the correct behavior.

This module uses personalized quizzes that help assess and then build the mathematical skills of a child. First, the child takes a quiz, the questions selected from the pool of questions. It follows the child's response and adjusts to the next level of questions depending on performance. Also, the system provides lessons for solutions. The quiz proceeds in this manner in the same way until a specific count is reached. Then the child's overall performance is displayed to parents by report.

It also has the feature aiming at the detection of the child's interest in different activities, for example painting, playing musical instruments, or quizzes. The process starts when the child chooses the category of activities from a given list. The system keeps records of attempts made in the different activities making statistical analysis on which activities are chosen most often. It is used to identify the fields that interest us. The system then proceeds to develop an elaborate report that will be provided to the parents.

In conclusion, this system is a vast tool for nurturing, not only, diagnosing various aspects of learning ability in children, but also it provides guidance in improving the said aspects. It incorporates some of the most recent technologies such as artificial intelligence or OpenCV and provides an enjoyable learning process that is based on games and motivation and is focused on child development.

3.1.2 Component-specific System Architecture Diagram

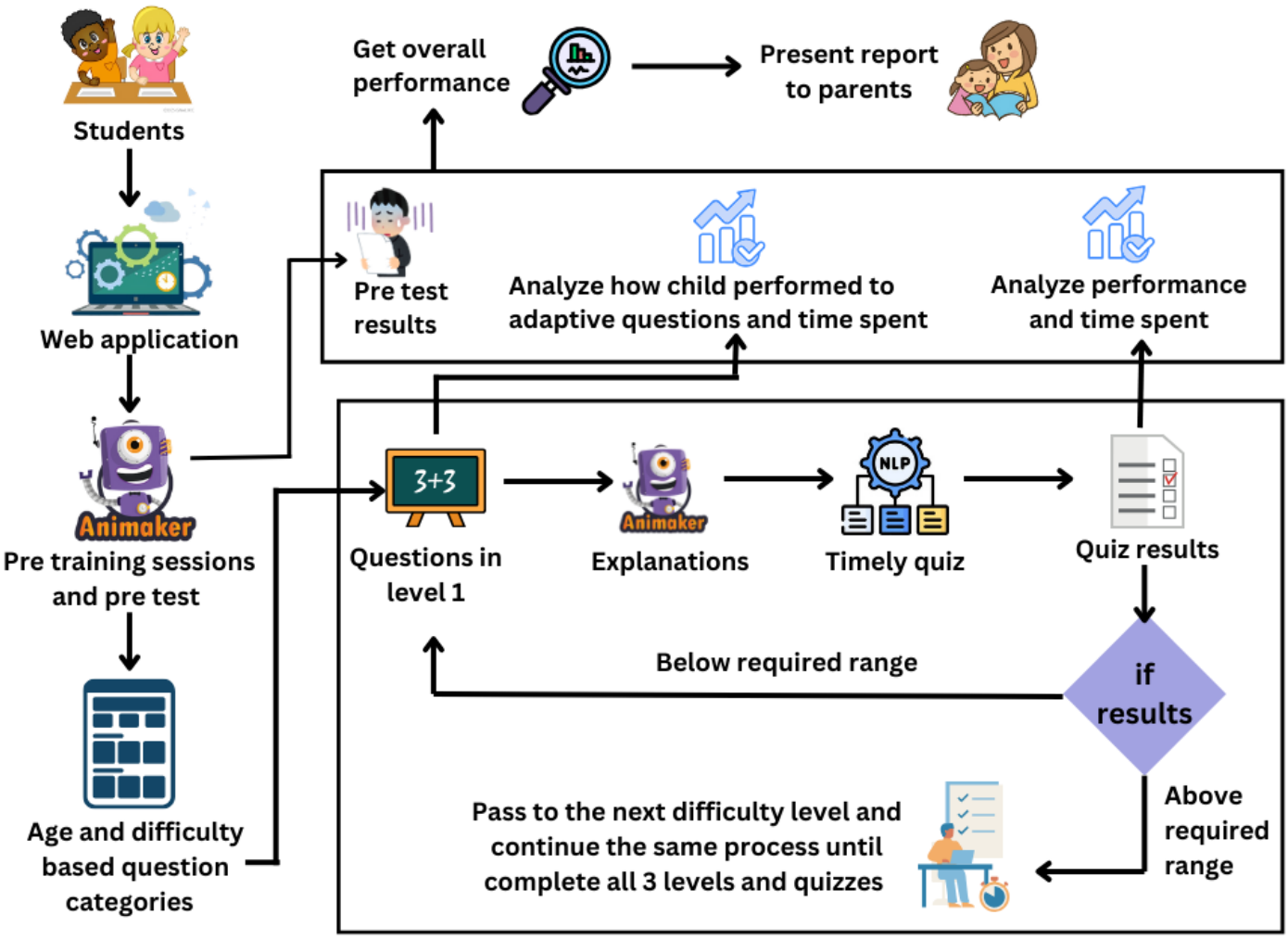

Figure 3.2 Component specific system architecture diagram

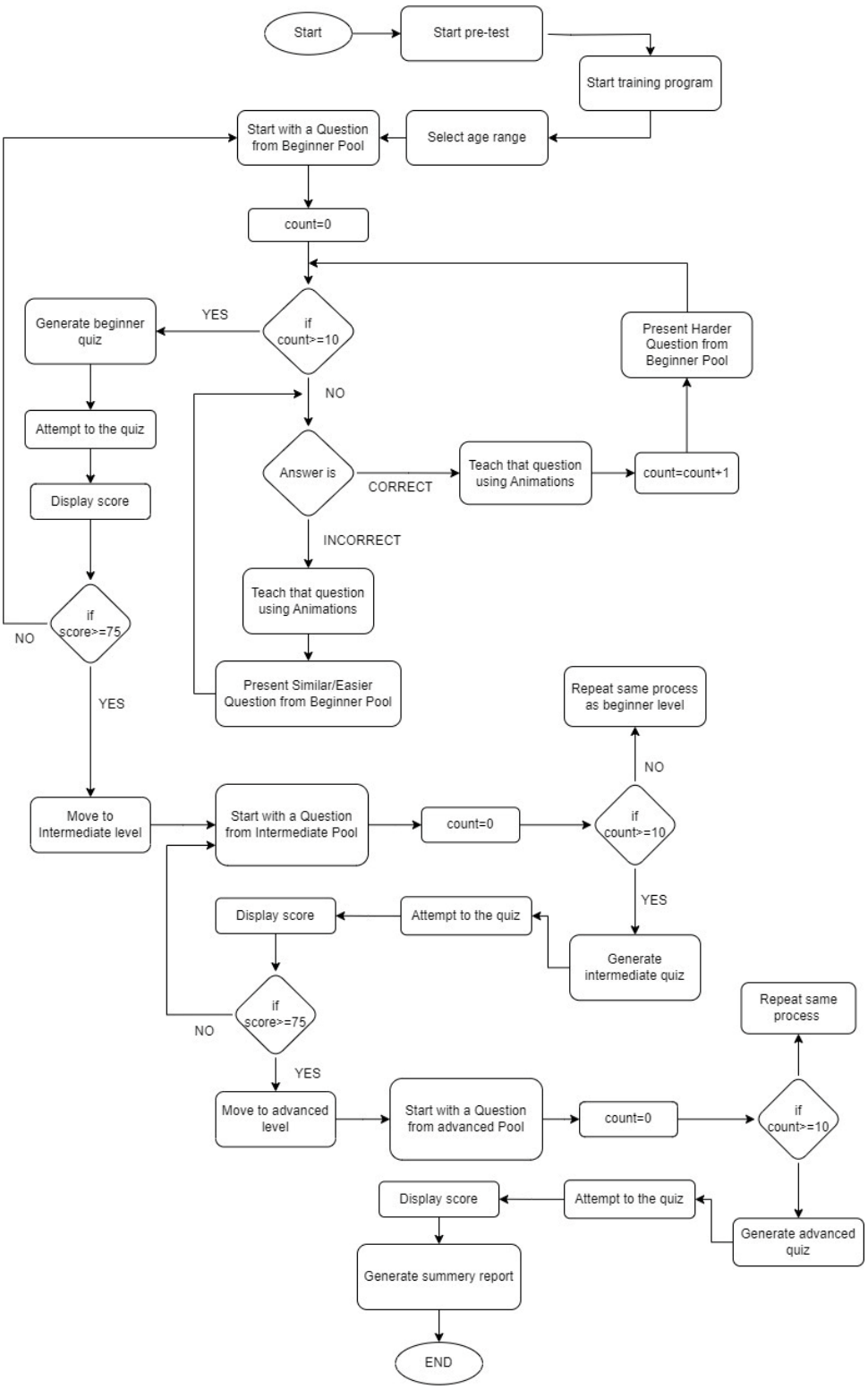

Figure 3.3 Flow Chart

Initial Setup Pretest and Training Program

The adaptive learning system for mathematical tasks is working with children to improve their learning skills of arithmetic concepts. It starts with a pre-test that aims at assessing the child's existing understanding of the content to be taught, which in this case is basic mathematics concepts. This pre-test is therefore used as a basis to develop the other training program about the needs of each child. After the pretest, the training program is provided to the samples for which basic arithmetic concepts and counting methods are taught. Such principles as [12], one-to-one principle, stable-order principle, cardinal principle, order irrelevance principle, abstraction principle, numerical order, and comparison are covered in this program [12]. The training also entails simple number operations such as addition, subtraction multiplication division; these small numbers are between 0 to 10.

To facilitate effective learning, the training program employs two primary teaching methods: The two methods are namely,

1 Kumon Method
2 Stern and Numicon Method

It uses paper and pencils to do the arithmetic, and progresses through steps in difficulty, as with the Kumon Method. On the other hand, the Stern and Numicon Method is more physical in a way that when assailing the numeracy concepts to children they are dealt with more tangibly. These methods are meant to address multiple approaches of learner information processing and repetition of arithmetic skills in separate ways. Also, all these methods are designed for DS children.

Question Pools

The structure of the functioning system embraces the clearly defined list of questions presented in numerous pools and divided according to the age of the students and the degree of their difficulties here, three pooled genres can be mentioned: Beginner, Intermediate, and Advanced. Every one of the question pools contains the simplest arithmetic operations. However, the level of complexity depends on the age category of the students. This way, it is possible to make sure that the questions offered are going to be neither too easy nor too complex to be beyond the child's understanding at the stage of development.

Adaptive Questioning

This is the key feature of the system, and this feature is adaptive questioning, meaning the level of the questions is chosen depending on the user's result. This way the system provides questions of slightly higher difficulty in case the correct answers are given, and questions of equal or slightly lower difficulty in case wrong answers were given.

Quiz

As soon as the users have answered a defined number of questions of each type of difficulty level, they are given a quiz intended to check on their general knowledge acquired during the game. The

quiz features questions chosen at random or slightly modified from the same pool; in each case, natural language processing (NLP) algorithms are used to select or synthesize questions on the pool. In a quiz, several aspects of performance are observed such as the time taken by the participant to answer questions and correctness of the answers being given. These show a simple percentage of the number of correct answers to the total number of questions. Those with total scores above a preset pass mark, a percentage for example 75 percent go to the next level of difficulty while those with low scores are detained at their level until they achieve the required mark.

Educational Animations

For additional learning support, the system combines educational animations developed with tools like "Animaker" or "PowToon." These animations are meant to help demonstrate mathematical skills, as well as offer solutions on what was done wrong in wrong answers. Animations used in the learning process add value to the teaching/learning process for two reasons; they make difficult concepts easier to understand because of the engaging format of the animations and the ability to keep the child interested in learning more.

Summary Reports

Last is the summary reports for parents: The system generates full summary reports for parents. These reports provide data on the child's progress at different grade levels, in terms of time taken, scores, and number of questions answered right or wrong. The reports also show progress over time with areas of specialty and areas that need improvement. Such detailed feedback gives parents the tool to track their child's progress in learning and in turn development.

3.2 Software Solution

3.2.1 Development Process

Agile methodology is a way of directing and creating projects and products that are sensitive to change. As opposed to a set plan that is seen in the typical approach seen in traditional approaches, the work is divided into smaller, and changes may be done along the process, making results timely and easy to react to them [23] [24].

Key Ideas of Agile Methodology

- Working with Customers: In Agile development, the team communicates with the customers and other people of interest. They receive feedback on the product to ensure that the requirements of the customers are addressed to the product.

- Small Steps (Iterations): The work is divided into short cycles, most commonly, it takes 2-4 weeks for a cycle to be completed. By the end of each phase, known as a 'sprint,' the development team delivers a tiny portion of the product that can be checked and evaluated.
- Flexibility: Organizationally, agile is designed in a way to respond to change effectively. If there is the latest information, like a new order from a client or a new trend in the market, the team can adapt easily [23].
- Teamwork: This is a team of people who are technical employees who work hand in hand, for example, developers, testers, and designers. This simplifies work with the aid of the respective teams and thus assists in getting the job done more efficiently.
- Constant Improvement: During each sprint, the team then goes through the process of identifying the strengths and weaknesses of what they did. This assists them enhance how they function in the subsequent fire sprint period.
- Focus on Working Software: Agile concentrates on providing frequentable such that each sprint delivers the real, usable parts of the product. In this way, the team always has something to execute and get feedback to ensure that they are on the right track [24].

There are separate ways to follow Agile, including

- Scrum: One of the most used in which the work is divided into iterations and the team has clear responsibilities (for example, the scrum master) and meetings to assess the situation.
- Kanban: A micro method of organizing work at the desk: there is a board consisting of columns that describes what stage of work the tasks are in.
- Extreme Programming (XP): Process that focuses on codes and their qualities such as Writing tests first before coding and partner programming [23].

Benefits of Agile Methodology

- Faster Results: Agile enables the delivery of parts of the product to the market faster so that the whole product can be delivered to customers faster.
- Easy to Adapt: It is easy for the various teams to switch direction should any new ISSUE arise during the process.
- Better Quality: In this way, the Agile team can diagnose the issues before the overall completion of the project and hence produce a better product [23] [24].

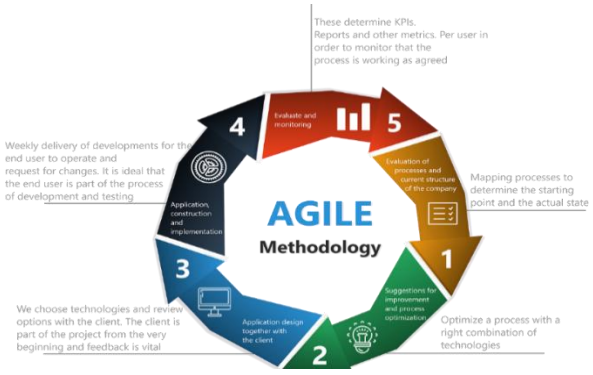

Figure 3.4 Agile Methodology

Source: *https://www.linkedin.com/pulse/agile-methodologies-nishtha-sharma-hp1kc/*

3.2.2 Requirement Gathering

1. Conduct Interviews

Employ the teachers, caregivers, and specialists at "Senehasa Research Center," to discuss the learning needs and difficulties of the children as well as current practices the children teachers use when teaching mathematics. Conference with the parents to get their perceptions about their kids' behavior, the areas that they excel at, and the areas they need to work on.

2. Observation

Go to the class and spend time with the children to note how they engage with the content and techniques they employ to solve Mathematics problems. Observe their ability to focus, the strategies they use to solve problems, and if there are any behavioral and learning characteristics noticeable.

3. Conduct survey

A survey is being taken as to what people feel about the research and how informed they are on DS. This research identifies whether the audience appreciates and recognizes the study and if there are any amnesias concerning DS. The outcomes will assist enhance the exploring element and convert its presentation so that it is fit to benefit as many people as possible

The study clearly shows general people's understanding of DS. 71.1% of the respondents are familiar with DS, and 68. 3% of them have encountered somebody with this condition. Precise to the above, 97.1% of the participants believed in the effectiveness of adaptive learning systems for the teaching of mathematics to children with DS and 76.3% deeming them valuable. Three percent consider them valuable. Additionally, 95. 4% of respondents agree that animated education is useful in assisting children in comprehending mathematical knowledge, with 67.1% rating it as highly effective. Conclusion: The results reveal that there is a consensus on the effectiveness of the adaptive learning systems and the educational animations in the improvement of mathematical learning for children with DS. This supports endorsements for incorporating those tools into educational programs

. These are the results of the survey,

1. Question 01- How familiar are you with DS?

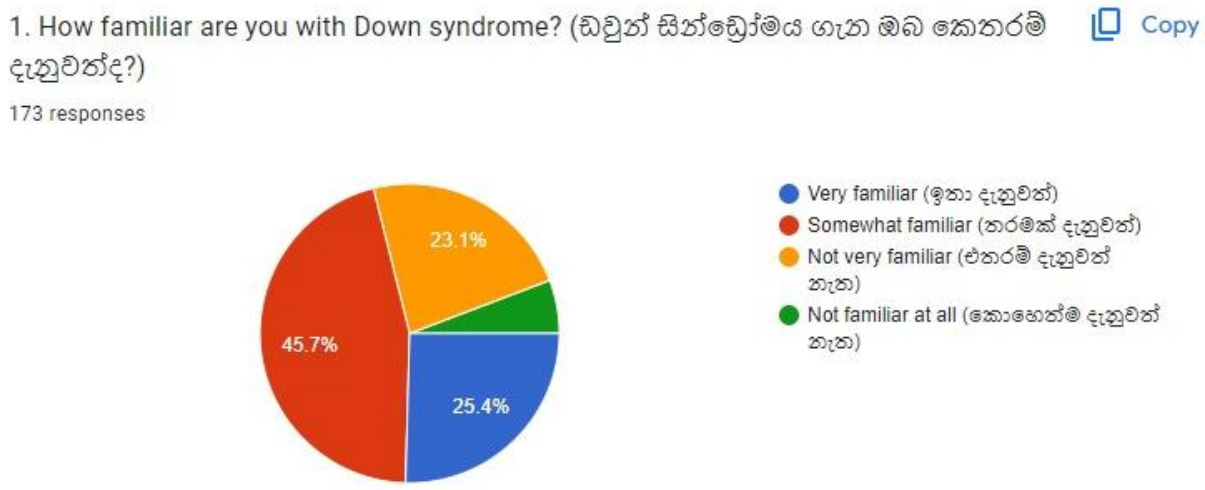

Figure 3.5 Survey results 1- Asking how familiar are they with DS

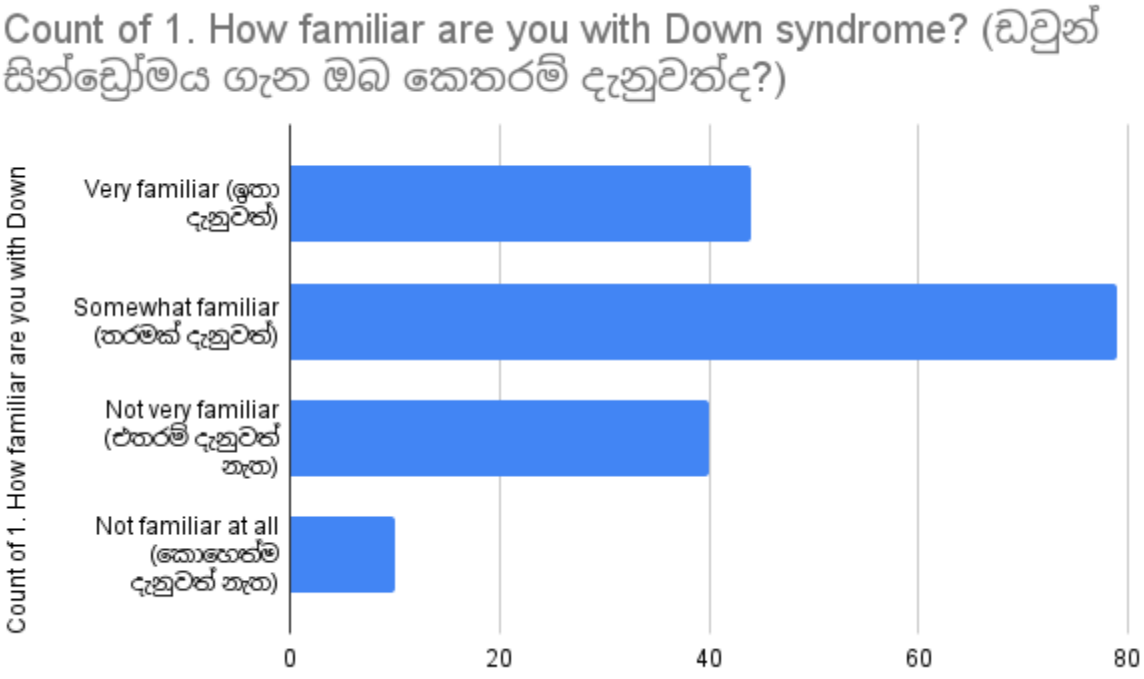

Figure 3.6 Survey results 1- Bar chart

2. Question 02- Have you ever interacted with someone who has DS?

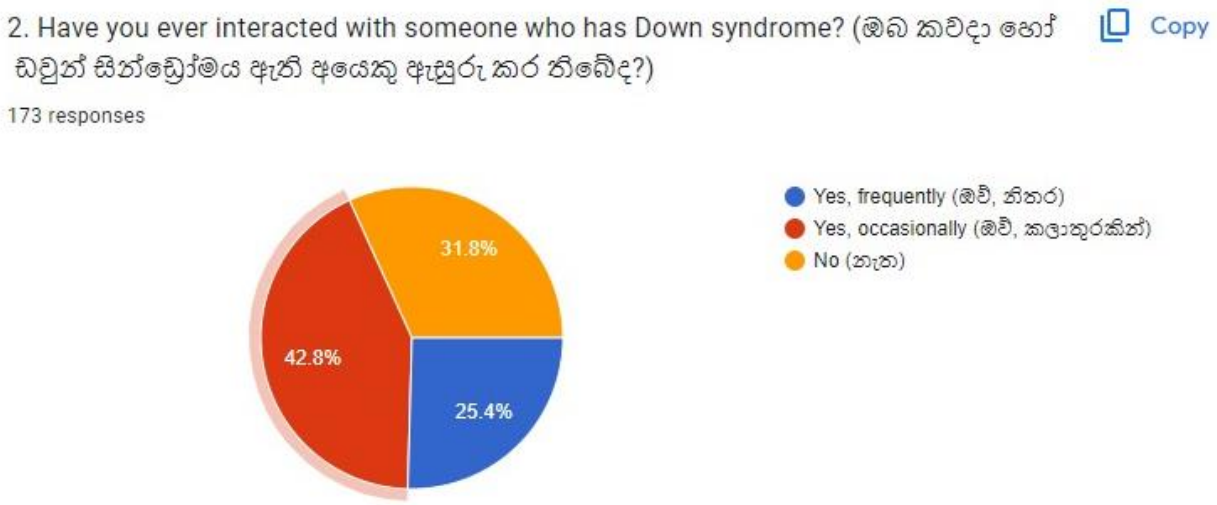

Figure 3.7 Survey results 2- Asking have they ever interacted with someone who has DS

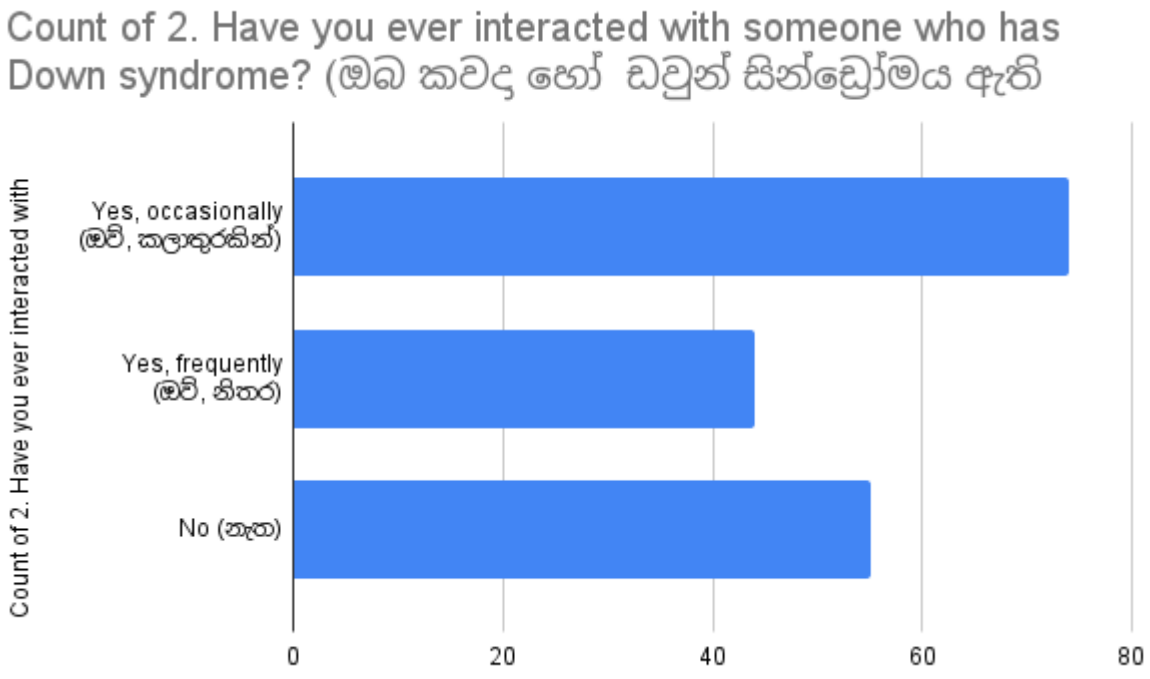

Figure 3.8 Survey results 2- Bar chart

3. Question 03- How valuable do you think adaptive learning systems for teaching mathematics?

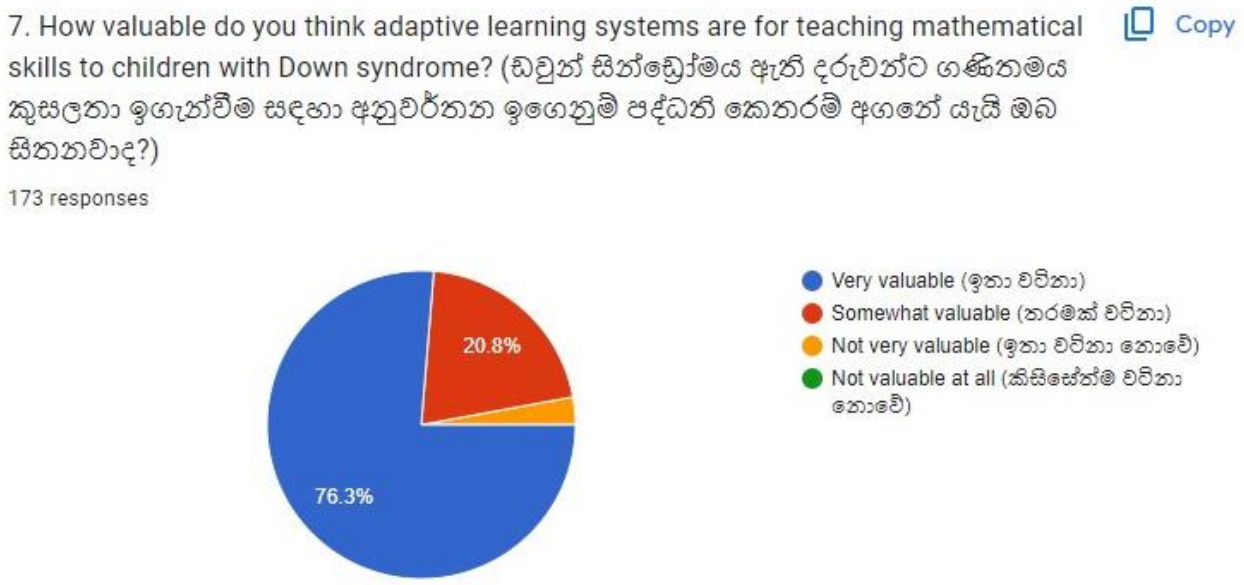

Figure 3.9 Survey results 3- Getting their opinions about teaching mathematics using adaptive system

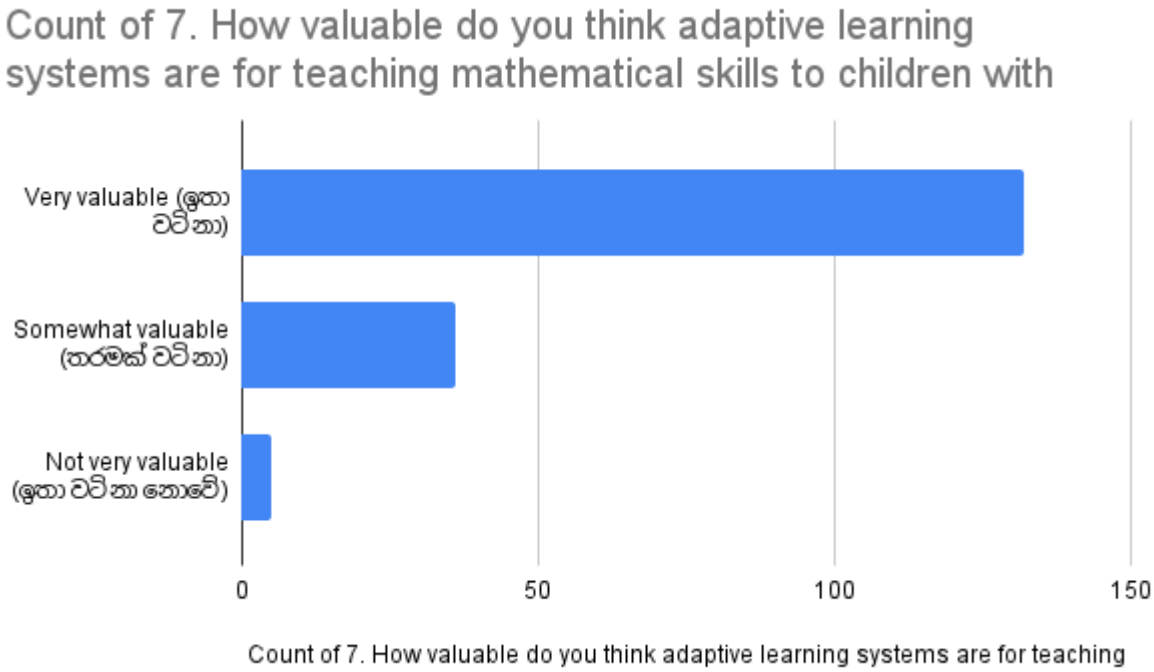

Figure 3.10 Survey results 3- Bar chart

4. Question 04- How effective are animations in helping children to understand mathematical concepts?

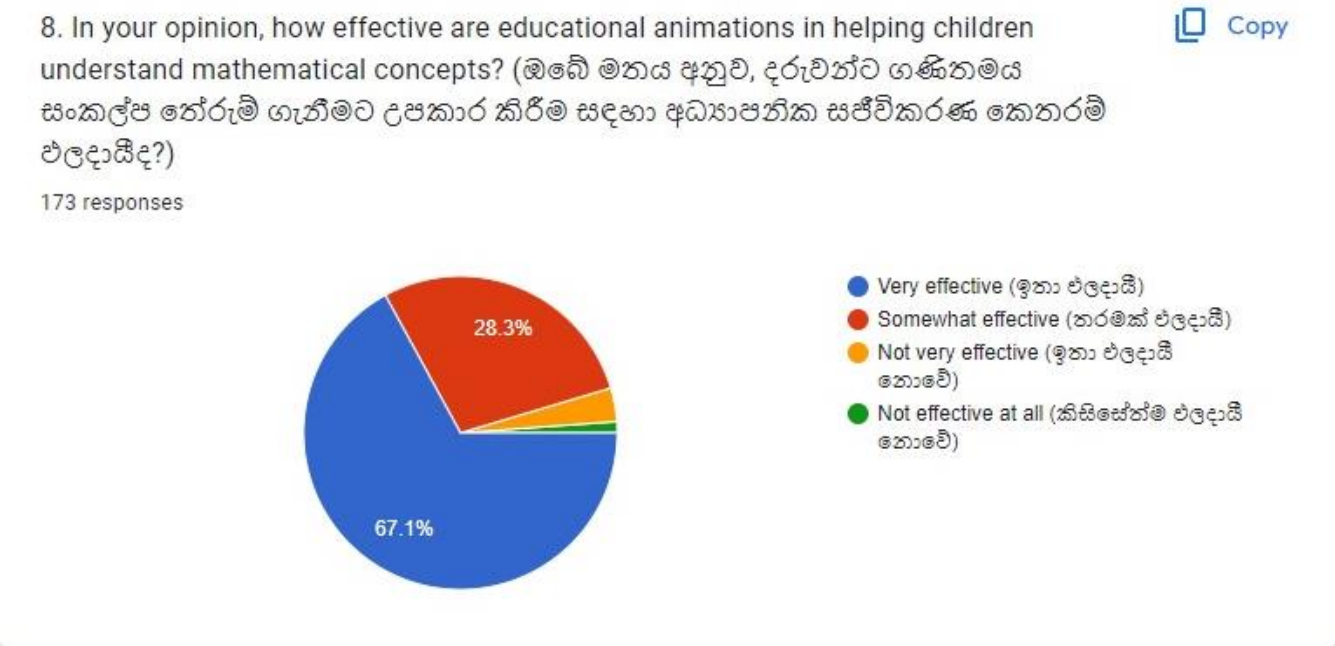

Figure 3.11 Survey results 4- Getting the opinions about integrating animations for learning process

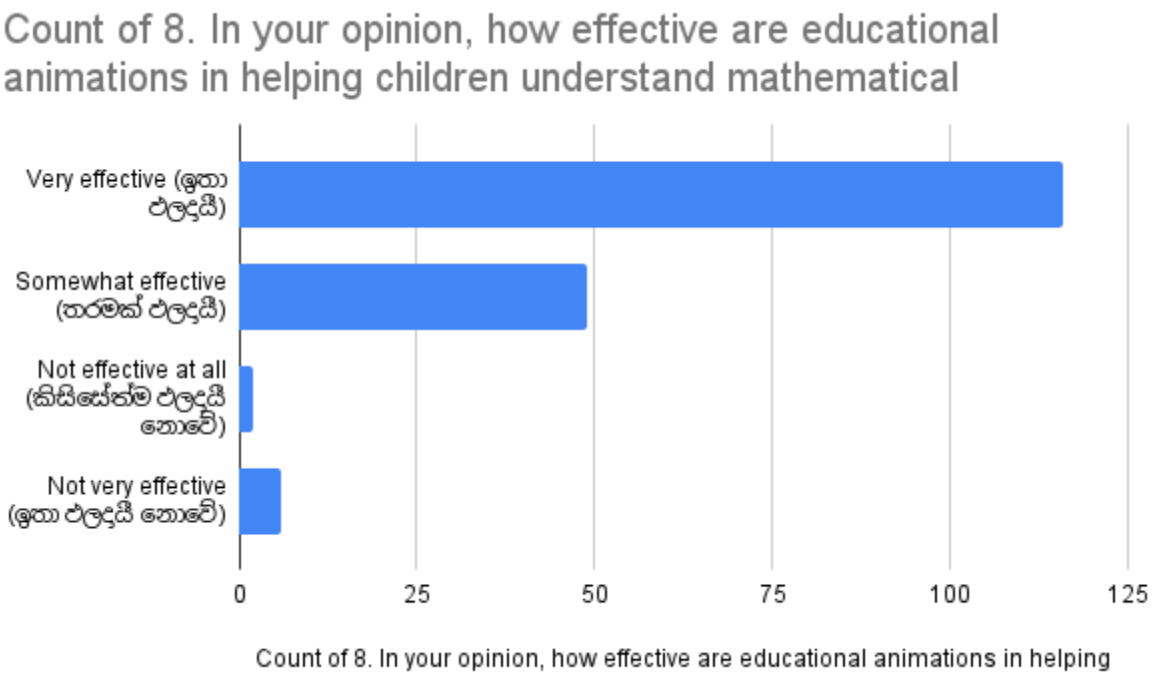

Figure 3.12 Survey results 4- Bar chart

4 PROJECT REQUIREMENTS

4.1 Functional Requirements

- Include a pre-test to evaluate the child's mathematical knowledge before he/she starts working through the system.
- To elaborate, it is necessary to point out that the results of the pretest should constitute the basis for the following training program.
- Explain basic mathematical concepts in a guided manner by instructed lessons making use of principles such as One-to-one, Stable-order, Cardinal, etc.
- Allow the use of various approaches such as the Kumon's and Stern/Numicon's.
- Categorize questions by age and difficulty level
- Create quizzes that automatically increase or decrease their level of difficulty depending on the scores that have been obtained by the student
- Add animation on the concept to be taught in stages
- Make the graphical user interface simplistic with elements of both graphics and sounds
- Track information about the user activity and how they perform at each level and then discuss the results with parents and generate user-friendly reports

4.2 Non-functional Requirements

1. Performance

- Be built for multiple concurrent active users. Performance will not suffer by behaving this way.
- The system was supposed to be very fast. Generate a quiz, then choose questions as swiftly as possible, so the default will always be to optimize response time for appearing in quizzes during trace determination.

2. Usability

- All facets of the application must be user-friendly for those with disabilities. Make sure to design an accessible and easy-to-understand interface that caters to all potential users.
- Make reports reader-friendly. Create a user, parent, and teacher-friendly way of presenting a generated report.

3. Quality

- Only if the reports are well written and reflect true user performance, thus being accurate, can we guarantee that quality. While going for reporting signaling, the report should be good to ensure the right activities have been performed by users so end-user needs get resolved.

4. Content and User Experience

- Includes educational materials and animations that are bright and lighthearted. Bright, fun educational material and animations are included.

5. Availability

- The system should always be ready, to make it ready 24/7 ensuring it is available for users whenever they require our service.

6. Security

- Save any part of these logs or performance reports using the software, together with personal data, in encrypted form during storage.

4.3 Software Requirements

- **Natural language processing (NLP)-** For Personalized Question Creation. With the help of NLP models, it is possible to analyze student responses and develop quiz questions for the students depending on the results and learning abilities. With a help of the most developed NLP approaches, hints, feedback, and even adaptive questions can be provided depending on the level of mastery of the child.
- **NLTK (Natural Language Toolkit):** With NLTK, it is possible to partition a text into different focus areas, meaning it can be used to sort out quiz questions according to the difficulty and topic.
- **GPT-3/GPT-4 APIs-** These could provide a method for personalizing the content of quizzes to reflect the student's progress.
- **Phyton-** This makes it easy to integrate with the major machine learning frameworks, where complex algorithms like neural networks can be incorporated to predict on the student's performance and the kind of quizzes that would suit them.
- **Animation tools like "Animaker" and "PowToon"-** Simply helps users have access to create animated videos with easy-to-use templates, characters, and assets. This can be useful for

educators and developers requiring creating educational materials with focus on non-animated objects while not requiring specialized animation skills.

- **D3.js library-** For the creation of dynamic and interactive statistics and graphics in web browsers. This provides better control on the features and using this feature can create complex graphical representation which is helpful for the analysis of student performance.
- **Chart.js library-** This is an easier-to-use and less complex library for creating charts and graphs. It incorporates many inbuilt chart forms and can be implemented in web applications. As it can be used to generate simple and uncomplicated graphic displays.
- **React-** For frontend creations

Algorithms

- **Rule-based system used for initial difficulty adjustment and to monitor and record the user progress:** Thus, defined rules help the system to understand how the student progresses and, therefore, how he becomes closer to advanced information.
- **Statistical Analysis for Tracking Performance Metrics and Generating Reports:** Statistical methods can track changes in the performance of students over time and hence the system can generate reports on learning progress. For instance, by using performance data it can be noted that the student's performance is gradually improving or that it is showing signs of deterioration constantly. This is also important in producing a detailed report of the student's performance for the educators and parents. These reports may consist of gains and losses of the student's performance, comparisons with previous attempts, and recommendations for further studies.

4.4 User Requirements

- **Students with DS:** Opportunity to take a pre-test to find out current level, get questions staggered according to the performance, and do quizzes to check improvements. Also, the system must be user-friendly for these children and easy to use and visually appealing.

- **Parents/Caregivers:** Get comprehensive reports in terms of scores, and overall performance of the child. Obtain information about the child so that parents and caregivers will be able to learn about the child's areas of positive behavior and behavior that require modification.

4.5 Test Cases

Test case ID: Test_01				
Test title: Pre-test assessment				
Test priority (High/Medium/Low): High				
Module name: Conduct a pre-test assessment				
Description: In this test case we check to ensure the system determines what a child already knows and does not know to provide an overall picture of what they are good at and where they can improve.				
Pre-conditions: The system has registered the child				
Test ID	**Test Steps**	**Expected Output**	**Actual Output**	**Result (Pass/Fail)**
Test_01	1. The child takes the pre-test. 2. Then the system determines the scores	• Complete the pre-test • Then generate a report on the knowledge the child has and the knowledge the child lacks.	• Complete the pre-test • Then generate a report on the knowledge the child has and the knowledge the child lacks.	Pass

Table 4.1 Test case 1

Test case ID: Test_02				
Test title: Training Program				
Test priority (High/Medium/Low): Medium				
Module name: Implementation of Training Program				
This use-case tests whether the system generates a training plan for an individual based on their pre-test scores, and monitors how well they are performing during exercises.				
Pre-conditions: The child has to complete pre-test and come out with results				
Test ID	**Test Steps**	**Expected Output**	**Actual Output**	**Result (Pass/Fail)**

Test_02	1. The system gives a training plan 2. Then the system determines the scores	• System displaying training activities • The child can follow exercises • System tracks their progress	• System displaying training activities • The child can follow exercises • System tracks their progress	Pass

Table 4.2 Test case 2

Test case ID: Test_03				
Test title: Adaptive Questions				
Test priority (High/Medium/Low): High				
Module name: Create adaptive question logic				
Description: This Test is created to check the functionality for the quiz system, it will monitor if a child's score affects question difficulty and raises or lowers points.				
Pre-conditions: The child signs in and take the quiz. The system assumes an adaptive questioning algorithm				
Test ID	**Test Steps**	**Expected Output**	**Actual Output**	**Result (Pass/Fail)**
Test_03	1. Select age range 2. Select difficulty level 3. The child attempts to the questions	• If the child answers correctly, the system provides questions of slightly higher difficulty. • If the child answers incorrectly, the system adjusts to provide	• If the child answers correctly, the system provides questions of slightly higher difficulty. • If the child answers incorrectly, the system adjusts to provide	Pass

Table 4.3 Test case 3

Test case ID: Test_04				
Test title: Quiz Evaluation				
Test priority (High/Medium/Low): High				
Module name: Conduct a quiz				
Description: This test case checks if the system can correctly evaluate how well your child scored on quizzes and scoring them based on time and correctness.				
Pre-conditions: The system has registered the child				
Test ID	**Test Steps**	**Expected Output**	**Actual Output**	**Result (Pass/Fail)**
Test_04	1. The child complete questions on selected difficulty level	• Top performers go to the next level. • Others work more on exercises. • The system calculates the child's score, considering the time taken and the correctness	• Top performers go to the next level. • Others work more on exercises. • The system calculates the child's score, considering the time taken and the correctness	Pass

Table 4.4 Test case 4

Test case ID: Test_05				
Test title: Educational Animations				
Test priority (High/Medium/Low): Medium				
Module name: Integrate educational animations for explanations				
Description: We will test the educational animations to determine if question explanations (after each quiz item) are correctly and interestingly explained through the system.				
Pre-conditions: The kid has done a question				
Test ID	**Test Steps**	**Expected Output**	**Actual Output**	**Result (Pass/Fail)**

Test_05	1. Select age range 2. Select difficulty level 3. The child attempts to the questions 4. Answer the question	• After answering each question, the system employs an animation as the feedback provided to the learner. • The animation should clearly and engagingly explain the correct concept.	• After answering each question, the system employs an animation as the feedback provided to the learner. • The animation should clearly and engagingly explain the correct concept.	Pass

Table 4.5 Test case 5

Test case ID: Test_06				
Test title: Summary Reports				
Test priority (High/Medium/Low): High				
Module name: Development of Summary Reports				
Description: The system provides detailed summary reports accurately reflecting the progress and strengths of the child as well as areas for improvement and development with using such kinds of equation requisites.				
Pre-conditions: The system has registered the child				
Test ID	**Test Steps**	**Expected Output**	**Actual Output**	**Result (Pass/Fail)**
Test_06	1. The child completes the quizzes and the training	• The system provides a detailed report. • It has such sections as the progress, strengths, areas of development, and goals with statistics. All the details should be correct.	• The system provides a detailed report. • It has such sections as the progress, strengths, areas of development, and goals with statistics. All the details should be correct.	Pass

Table 4.6 Test case 6

4.6 Design

4.6.1 Use Case Diagram

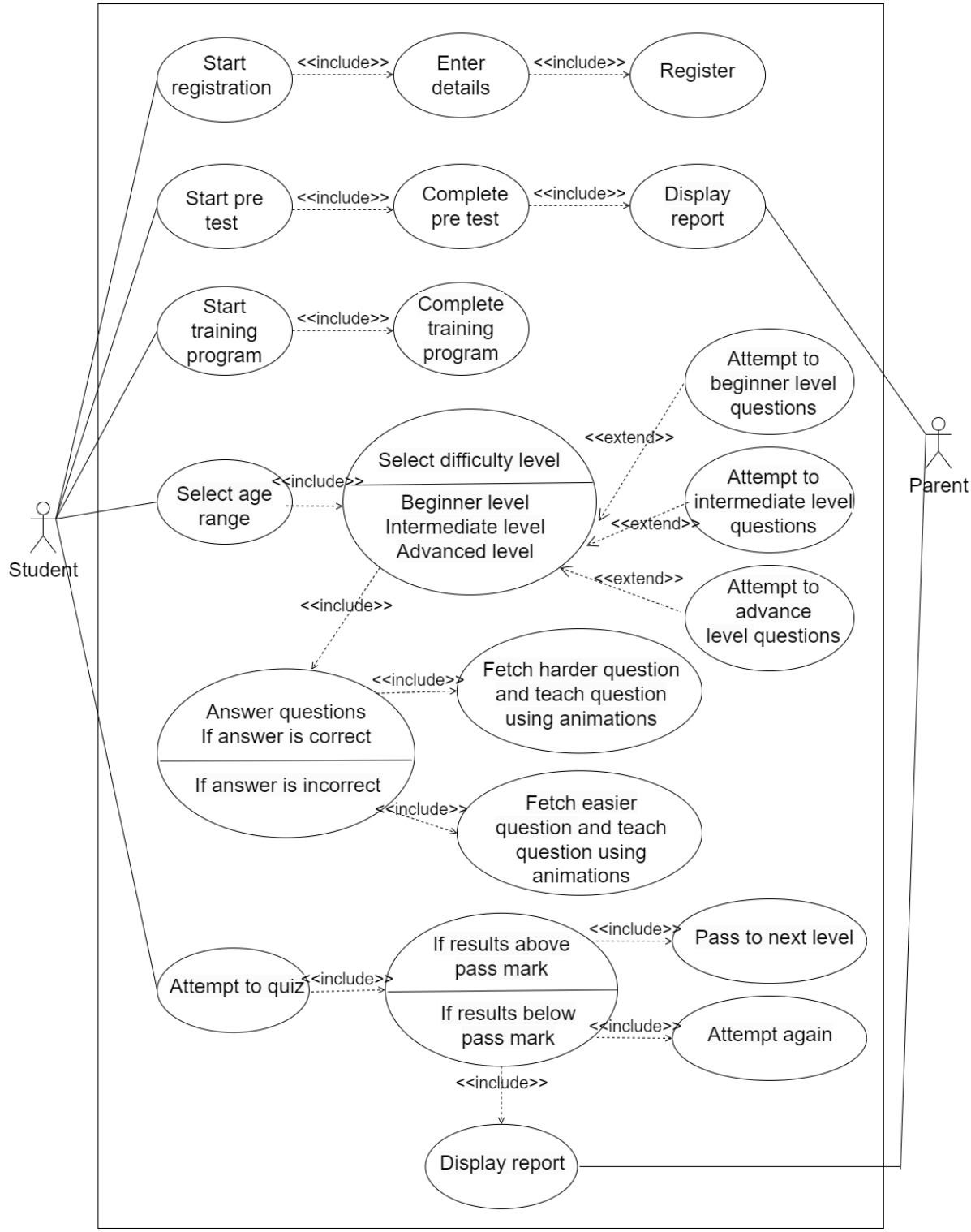

Figure 4.1 Use case diagram

4.6.2 Sequence Diagram

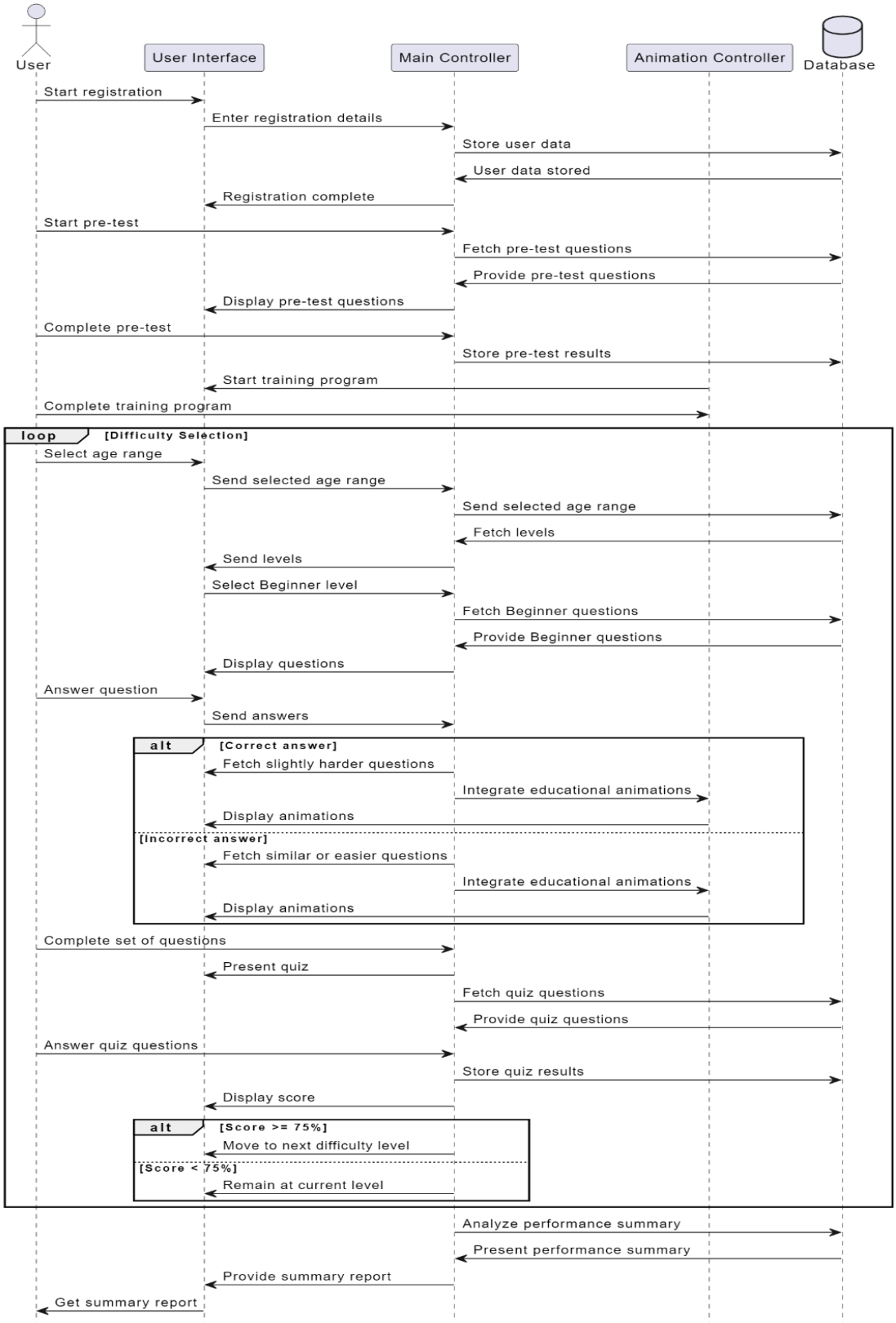

Figure 4.2 Sequence diagram

4.6.3 Wireframes

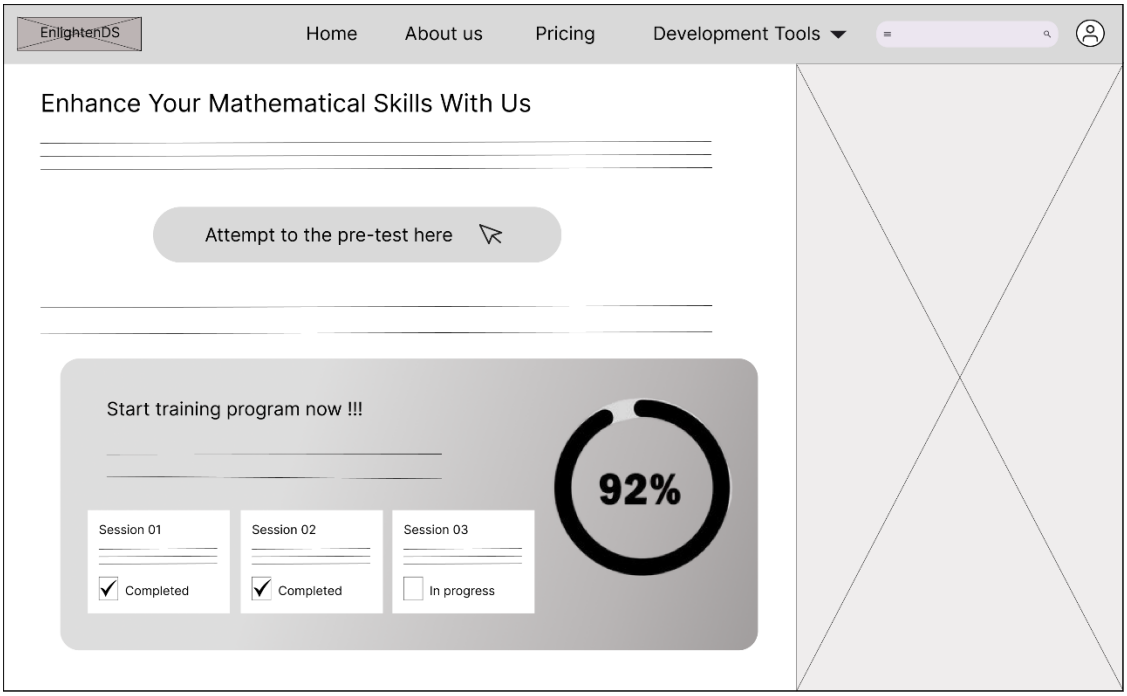

Figure 4.3 Wireframe 1-Main page

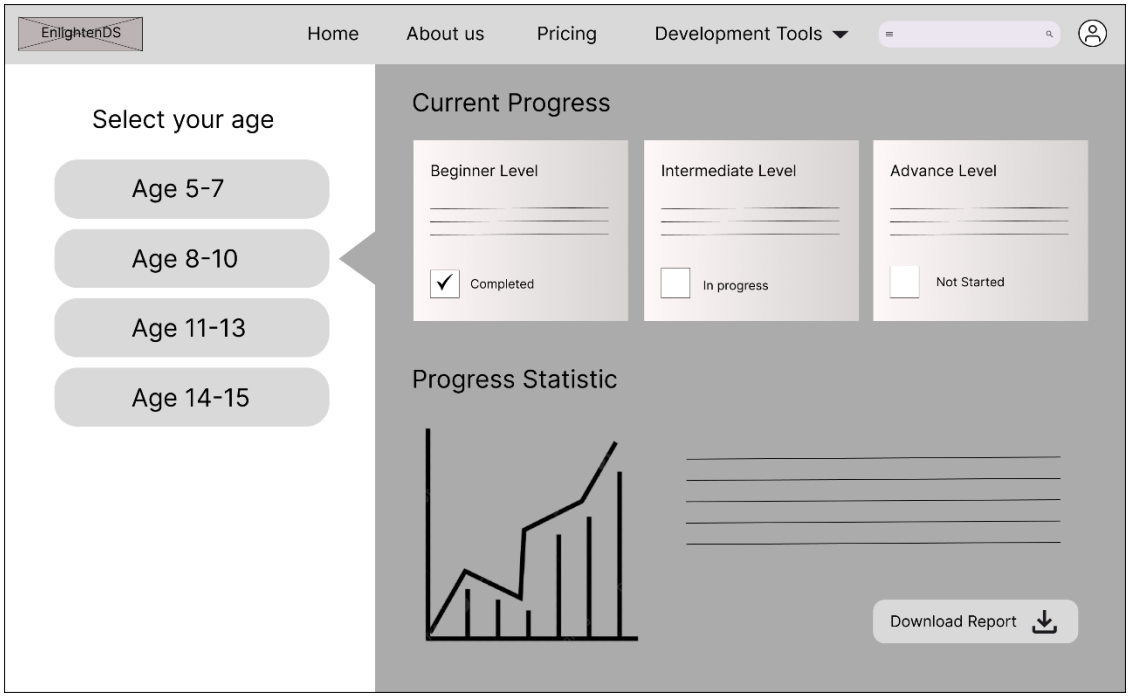

Figure 4.4 Wireframe 2- Progress tracking page

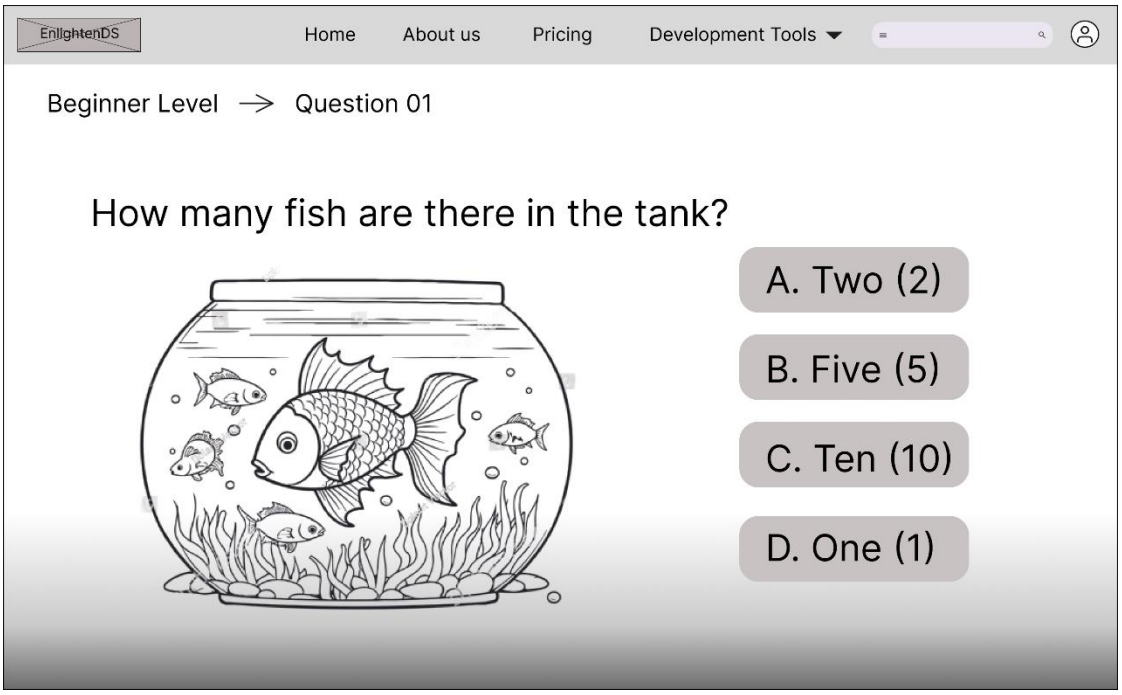

Figure 4.5 Wireframe 3- Questions page

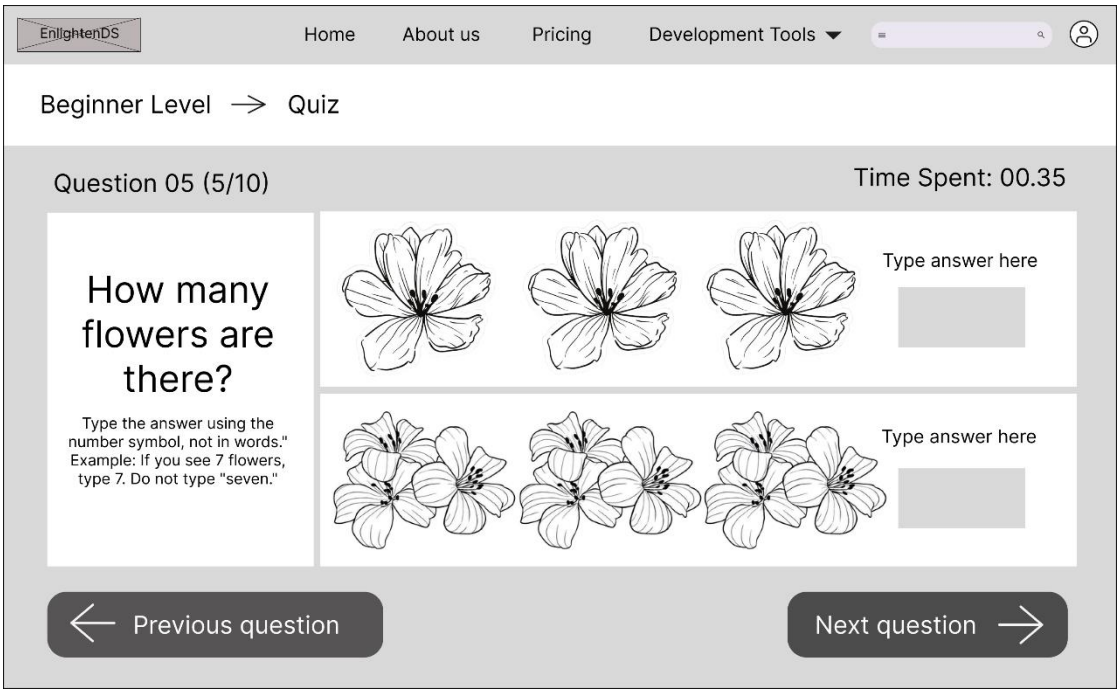

Figure 4.6 Wireframe 4- Quiz page

5 COMMERCIALIZATION PLAN

1. Market Analysis

Target Audience

- Children with DS age 5-15
- Parents, caregivers, and schoolteachers
- Healthcare professionals working with children with special needs

Market Size and Trends

- Increasing awareness and demand for individualized educational help for children with special needs and increasing adoption of technology in the learning process, especially in special education

2. Revenue Model

1. Freemium Model
    - Offer a free, basic version of the system, with reduced features.
2. Subscription-Based Model
    - Users could have a subscription service on a monthly or annual basis for parents and institutions and have tiered pricing based on features/levels of access (basic, premium)
3. Institutional Sales
    - Partner with schools and educational institutions by offering bulk subscriptions.

3. Packages and features

1. Basic Plan
    - Features
        - ✓ Access to cognitive-level assessment tools
        - ✓ Basic communication skill improvement activities
        - ✓ Limited personalized quizzes for math skills
        - ✓ Access to painting and piano platforms to develop creativity
        - ✓ Basic summary reports for parents with scores and spent time
    - Price: Free

2. Premium Plan
    - Features
        - ✓ All features from the Basic Plan
        - ✓ Advanced cognitive assessment with detailed symptom analysis
        - ✓ Full access to personalized quizzes with adaptive difficulty
        - ✓ Emotion-based engagement activities and mood detection

- ✓ Advanced summary reports with performance improvement statistics.
- ✓ Priority customer support.

- Price: $10 per month

3.School/Institution Plan

- Features
  - ✓ Bulk subscriptions with discounts for schools and educational institutions.
  - ✓ Access up to 40 students.
  - ✓ Full access to all features for multiple users [Students].
  - ✓ Training and supporting educators to include it in the curriculum.
  - ✓ Detailed analytics and reports for educators on student progress
- Price: $30 per month

6 BUDGET

Component	Amount
Travelling cost	10000
Server and hosting charges	25000
Internet charges	15000
Total	50000

Table 6.1 Budget

7 GANTT CHART

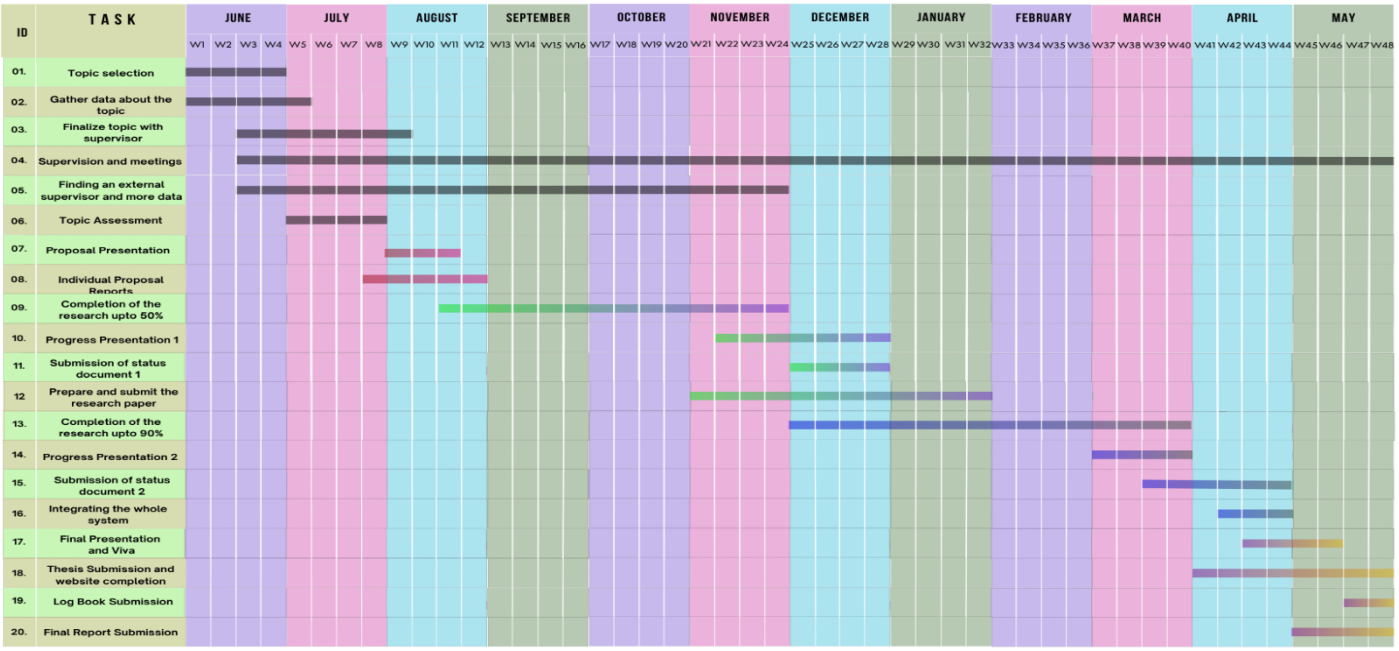

Figure 6.1 Gantt chart

8 WORK BREAKDOWN STRUCTURE

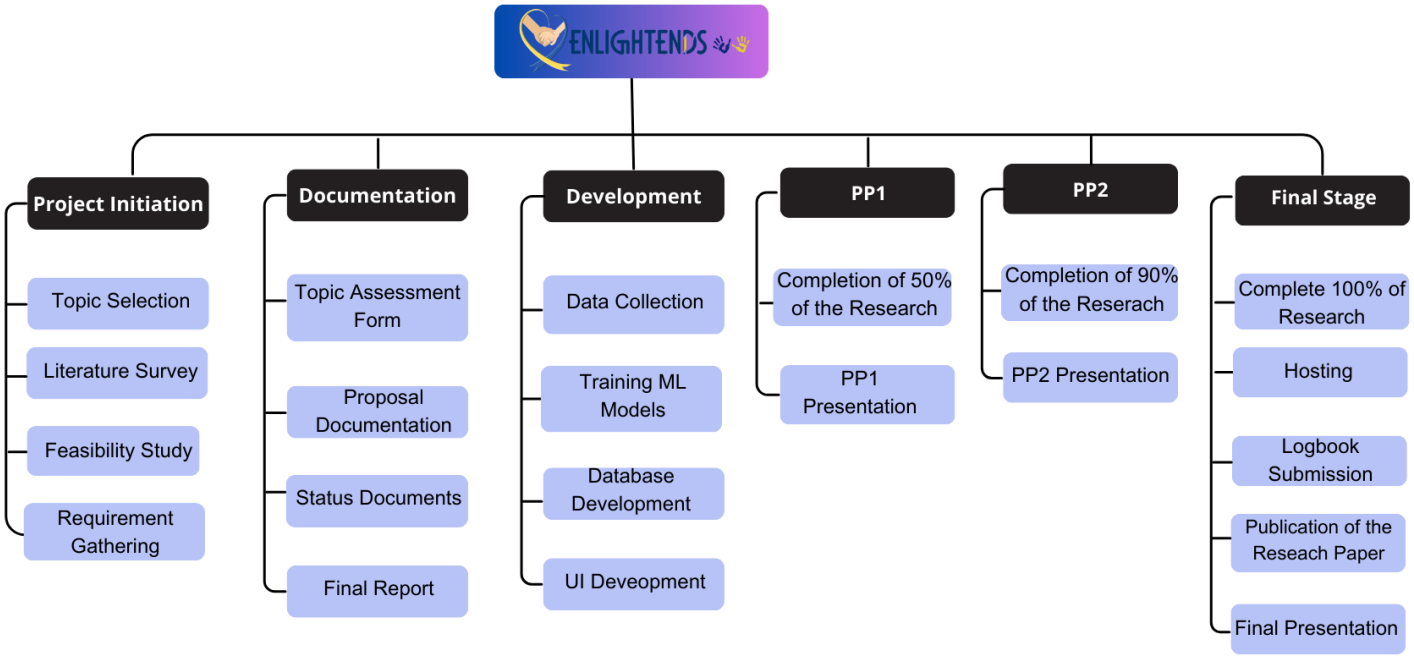

Figure 8.1 Work breakdown structure

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APPENDICES

Survey Link - https://forms.gle/QAtP4zw7gkEtuYQ47

Plagiarism Report –

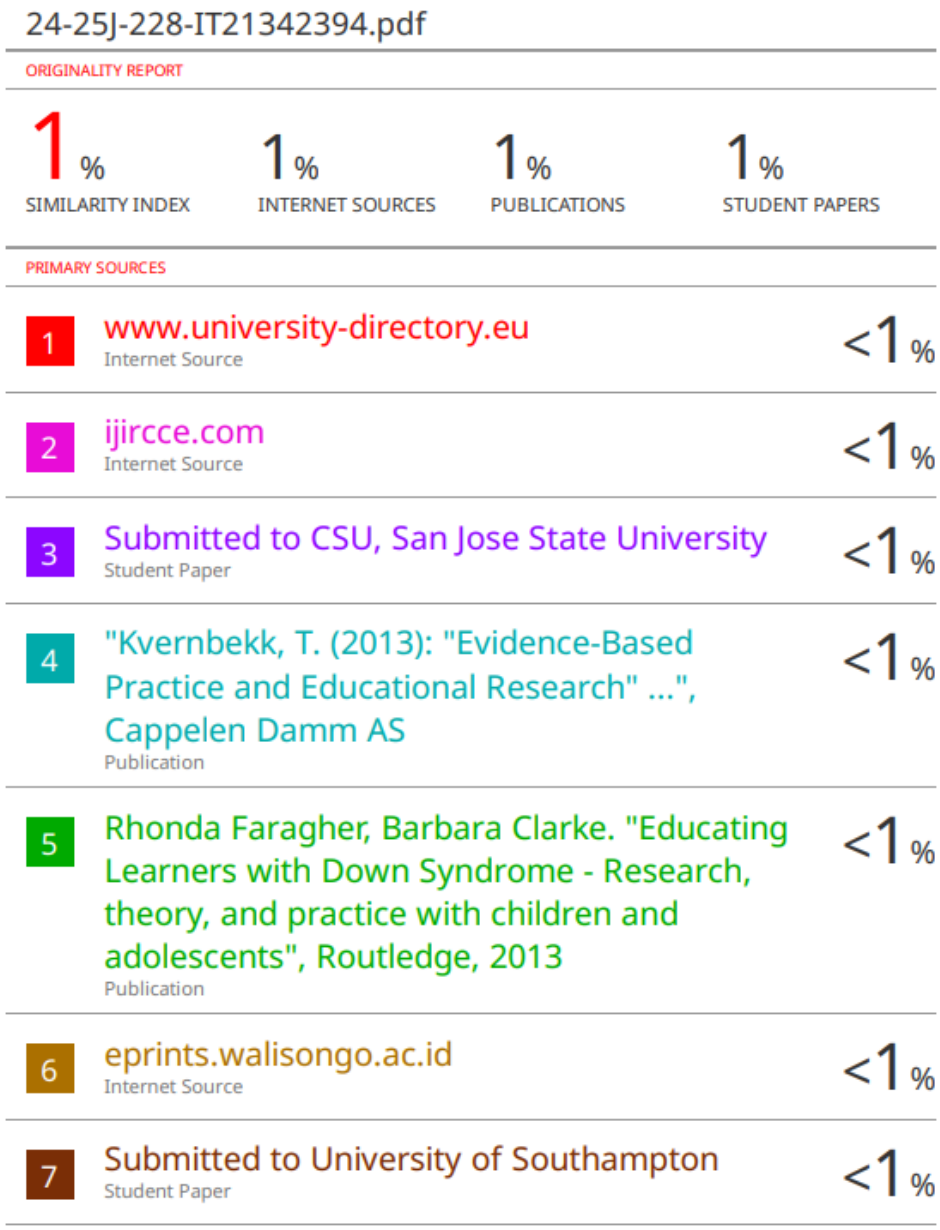

Figure 0.1 Plagiarism Report 1

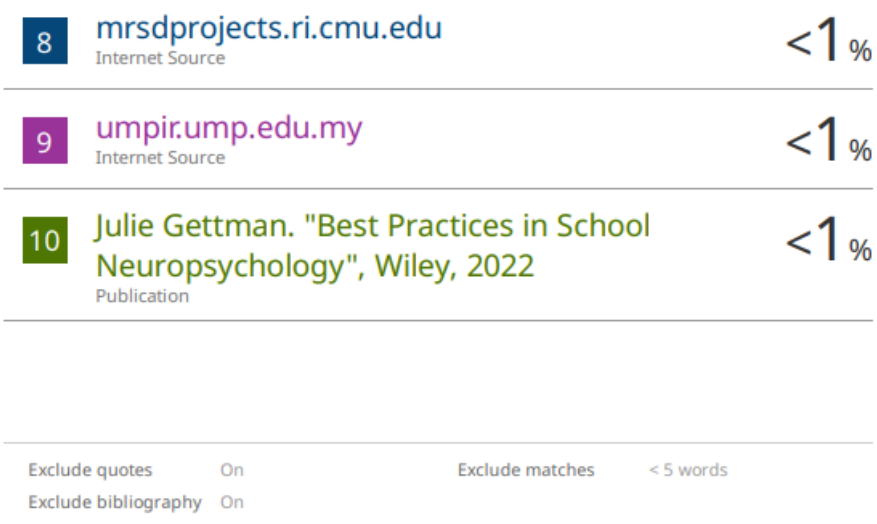

Figure 0.3 Plagiarism Report 2

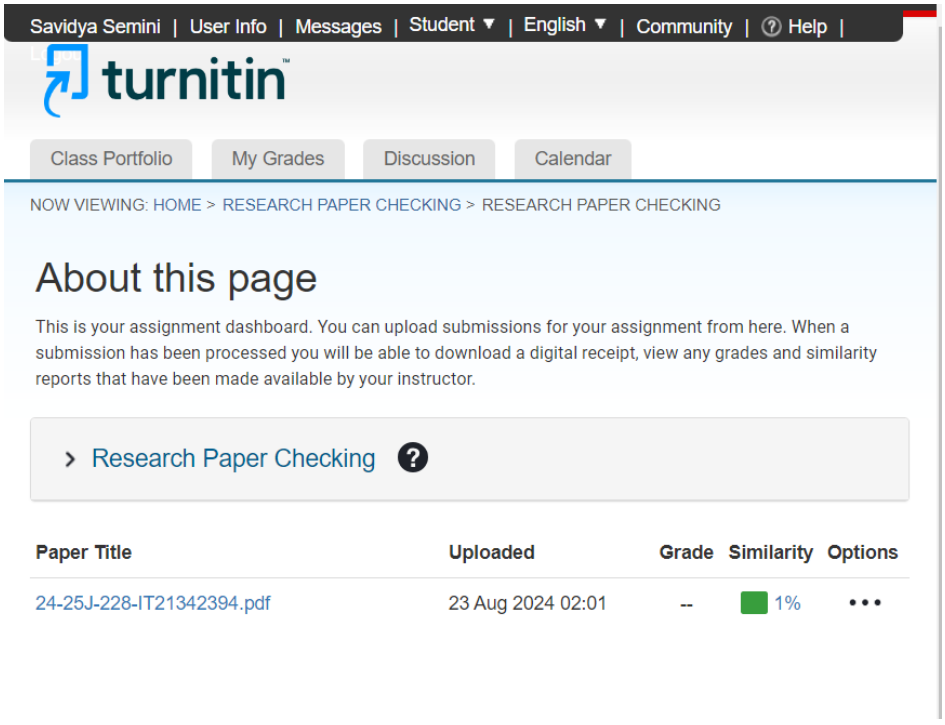

Figure 0.2 Plagiarism Report 3