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The Proposed Conceptual Framework to Enhance Mathematics Abilities on Children with Autism Spectrum Disorder (ASD) Through the Application of Virtual Reality Technology

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Abstract

The teaching of mathematics to autistic students has not garnered significant attention. In truth, many autistic children are proficient in mathematics, and some are even exceptional. It requires teachers to develop and implement effective ways for teaching

autistic children. Word problems allow students to practise real-world applications of mathematics through the application of computational procedures in analytic reasoning. To create an accurate situation model of a narrative text, it is necessary to visualise the events described in the text. As children with autism spectrum disorder (ASD) connect to many academic and cognitive elements, it is difficult to help them achieve competency in word problem comprehension. Using virtual reality learning technology, the study aims to uncover the conceptual framework of word problem comprehension among autistic children. Autism children may benefit from a virtual reality learning environment for those with cognitive and perceptual difficulties. The technology can aid in planning, problem-solving, and behaviour control and provides effective communication tools for individuals with limited expressive language. To design a research objective, comprehension of these children's learning capacities in answering word problems was undertaken. The project investigates the incorporation of virtual reality into the learning of word problems as part of a treatment that will aid children in comprehending the problem situation. This project's completion will contribute to the range of technology applicable to special education.

Keywords— autism; mathematics; word problem; virtual reality; situation model.

Introduction

Every child in Malaysia has the right to an education that allows them to achieve their particular potential according to the Malaysia Education Plan 2013-2025 (PPPM 2013-2025). Malaysia has signed and ratified the Convention on the Rights of Persons with Disabilities in 2008 which calls for the improvement of education quality and recognises the right of persons with disabilities to education. Hence, it is essential for teachers to have the ability to overcome any limitations presented by students, regardless of physical, mental, or social limitations. The People with Disabilities (OKU) Registration Form identifies six sub-categories of learning disabilities: global developmental delay (GDD), down syndrome, attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), intellectual, and specific learning disorders including dyscalculia, dysgraphia, and dyslexia.

In Malaysia, it is predicted that 9,000 newborns will have autism each year (National Autism Society of Malaysia) [1]. Autism spectrum disorder (ASD) is defined as a lifetime, acute psychoneurotic developmental disability that develops during early childhood and restricts or hinders daily functioning. ASD is one of the learning disabilities diagnoses in Malaysia which have gradually increased over the past decade,

according to the Ministry of Health (MOH) data. This is also supported by the research done by [2] which stated that the global prevalence of autism has risen to 100 in 10,000 (or 1 in 100), up from 62 in 10,000 a decade ago. The research concluded that "many variables," such as "increased community awareness and public health response globally," "improvement in case identification and definition," and "increased community capacity," were responsible for the rise in prevalence. Being one of the most rapidly expanding neurological disorders, there is a need to adapt educational technologies application to meet the needs of children with autism.

The children with ASD may have comorbid disorders that make the usual school setting problematic. Studies of developmental difficulties in children with ASD have revealed subtle distinctions in how these disorders affect their cognitive, linguistic, communicative, and social capacities. Children with ASD generally have problems with attention, information processing, and social cognition, as documented by researchers like Baron-Cohen, Leslie, and Frith (1985) and Frith and Happé (1994). Problems with information integration, abstract reasoning, and cognitive flexibility were also characteristic of individuals with ASD [4].

There has been a surge of interest in recent years in assisting ASD children to succeed in their mathematical studies. Mathematics is an essential academic skill for all students, especially ASD children, in order to achieve self-sufficiency in life functioning and social community. [5]–[7]. Word problem (WP) solving is one area of focus for the researchers. WP is a math exercise that ties solutions to real-world problems to mathematical ideas that are explained in words instead of mathematical notation. WP is significant because it includes abilities and functions that are required in daily life [6]; [8]-[11]. WP, on the other hand, is a difficult activity for children with ASD since it demands not just mathematical skills but also reading comprehension, memory organization, and real-world reasoning [12]. Hence, the use of virtual reality in the mathematics problem-solving education of children with autism is vital, as it can facilitate the effective learning of mathematics problem-solving by children with ASD.

For over twenty years, there has been a growing body of research into the potential of VR as a teaching aid for students with autism spectrum disorder (ASD). Scientists have found that virtual reality (VR) can help students with autism spectrum disorder (ASD) learn [13]. This is because virtual reality (VR) allows us to replicate any event and learning context, tailoring it to the student's sensory preferences [8], and allowing us to define, control, and manipulate the degree and number of characteristics of spoken and nonverbal communication [9]. In addition, the visual-spatial learning style that has been found to be a particular strength and primary channel for children with ASD is well-suited to the

immersive environment provided by VR technology [14]. In addition, it enables the frequent and methodical execution of activities in environments that are highly analogous to those in the real world, but without the associated risks [15].

The importance of mathematics in helping children with autism spectrum disorder acquire the abilities necessary to keep up with today's fast-paced technological world cannot be overstated. According to the National Council of Teachers of Mathematics [16], "mathematical competency" and "the ability to employ mathematical skills in everyday life and in the future" are essential for all students. Thus, the students in the Malaysian Special Education Curriculum (Learning Issue) are expected to employ information and communication technology abilities that are up-to-date with technological advances.

There is minimal research on WP solving abilities in children with ASD. Early detection of WP issues allows for early treatment of the student. As a result, effective teaching strategies using VR can be used to aid students with learning difficulties, which will have a positive impact on their future lives and careers. Thus, the purpose of this research is to provide a proposed conceptual framework for teaching autistic children word problem comprehension using VR technology. This study has two specific objectives: (a) to determine the word problem-solving abilities of autistic children, and (b) to determine how a virtual reality environment can be integrated into the word problem-solving learning process.

Background of Issue / Problem

A. Ability to Solve Word Problems

J. R. Root is the most pertinent researcher in the field of mathematics problem-solving and mathematics learning of students with autism spectrum disorder. J. R. Root formed a bibliographic coupling relationship with 41 authors, with a total frequency of 609 reference overlap. J. R. Root has authored two articles in 2019 and 2017, respectively. According to [17], teaching word problem-solving to children with ASD may be twice as tough as educating children without a learning disability. This is due to the fact that the majority of students with ASD have been diagnosed with intellectual difficulties and a low IQ [18].

The criteria for School Mathematics stress a solid grasp of mathematical concepts, a high level of procedural knowledge, and the capacity to apply mathematical knowledge to solve real-world issues [16]. Hence, regardless of whether a student has a disability or not, all students are expected to develop the requisite maths skills. Despite the fact that it involves a number of academic and cognitive components, assisting children with ASD in developing competency in WP solving has proven to be difficult [8], [19].

WP is a mathematical exercise in which the problem's information is delivered as text rather than mathematical notation. WP requires students to utilise both semantic and arithmetic skills to solve problems [12]. Students with autism, on the other hand, have difficulty understanding the problem situation or semantic information due to their linguistic impediment [22]-[24].

In addition, WP frequently incorporates contextual information or knowledge that children may encounter in their daily lives [8]; [19]; [25]; [26]. Due to their little experience with the community and their limited and repetitive patterns of behaviour; interest, or interests, [27] the youngsters will find the learning process tough.

This result is comparable with the findings of previous studies [28]–[30], which revealed that autistic children with an IQ of 80 or higher or High Functioning Autism (HFA) may have difficulties with WP solving and mathematical reasoning.

Mathematical reasoning is related to Cognitive ability since it assists in comprehending a problem circumstance and adjusting to solve a new problem. Thus, when solving WP, students will apply their understanding to real-world problem scenarios in which mathematical reasoning has become an essential tool for making tangible judgements.

B. Possible Benefits of the Virtual Reality Learning Environment

VR is a digital and physical learning platform that has been successfully designed to aid learning [31-33]. The mechanism is a 3D simulation of a real-world learning environment capable of constructing everything imaginable, with users able to interact with the environment [34]. The VR learning environment is experiential and intuitive; hence, it provides a novel learning experience comparable to hands-on learning, simulation, and concept visualisation.

In recent years, VR-based interactions between human-computer interaction activities have been recommended for ASD intervention. VR has various advantages, including its immersive, controllable, replicable, sensory, stimulating, and intervention and enhancement of individualised learning methodologies. The three main advantages of using VR are as follows: (1) Virtual reality enables users to experience real-world scenarios [34]. (2) Virtual reality can foster a sense of social presence in cyberspace [34]; [35] (3) Embodiment in VR will provide the user with a sense of self and presence, which can encourage a higher level of cognitive interaction with other avatars [35].

Moreover, the qualities of active, authentic, and contextualised learning processes obtained from VR's interactive experiences can facilitate the user's comprehension of abstract concepts [36].

C. How does a virtual reality (VR) learning environment help students improve their mathematical word problem comprehension?

The virtual reality (VR) learning environment capitalises on the visual learning ability of ASD individuals. To support the development of mental representations, the virtual reality (VR) learning environment presents the learner with a virtual scenario representing the textual information in the word problem.

The controlled visual content can be explored and interacted with repeatedly. Children with ASD are able to actively participate in interactive and immersive simulated circumstances by experiencing a virtual environment as if they were physically present. In a virtual scenario including the buying and selling of goods or services, for instance, it will provide pupils a sensation of presence in the buying and selling activities. As the learner engages in the maths activities, they gain everyday experience with mathematical knowledge and develop their contextual knowledge. Moreover, visual and sound were efficient in teaching abstract concepts to autistic children [38].

Interactivity in the VR system, which arises from interactions between the user and the avatar, can facilitate the creation and representation of mental models. VR can stimulate the imagination by evoking memories of images or concepts of object, event, and circumstance that were created by mentally mixing past interactions with objects and situations. Because the text of information and world knowledge interact continuously, [39] it is useful in the formulation of the problem scenario. In this aspect, VR has the potential to assist learners in building accurate mental representations or situation models during word problem comprehension.

Visualizing and constructing the situation model enables the student to clarify the text's semantic content. This affects the students' ability to comprehend the word problem.

It is observed that the method is consistent with constructivist principles [40]–[48]; and it is proposed that VR technology can be incorporated into learning Processes in order to enhance ASD children's grasp of the context of mathematics knowledge in real-world problems. The VR experience is anticipated to facilitate the creation of problem situations that will aid children in solving WP.

D. Problematic Situation

To comprehend a narrative text, the reader must develop a mental image or situation model [39]. Situation model refers to the mental representations of the event in the text that are produced by the reader as he or she reads. During the building of the situation model, text information and world knowledge interact continuously, according to [39]. Prior to drawing any conclusions about the subject they are

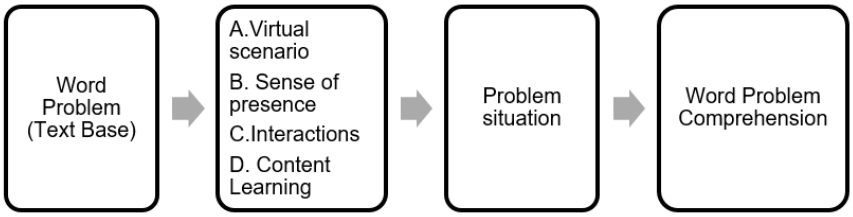
reading, readers frequently rely on their past knowledge and terminology. Thus, without accurate mental representation, comprehension and understanding will be limited. Moreover, research has demonstrated that mental imagery improves reading comprehension [43], [44].

Relevant background information must be available and active in a student's memory in order to construct an appropriate representation of the scenario in the text [45]. According to research, youngsters with limited prior knowledge scored lower on comprehension tests [46]. It was backed by Norman's (2014) discovery that children's mental representations are built on their prior knowledge and experiences. Consequently, it may be argued that youngsters are more likely to comprehend the problem provided in the text if they have a substantial quantity of past knowledge.

E. Conceptual Structure

The framework study consists of (i) a study of WP abilities among autistic children and (ii) an intervention solution involving the use of a VR learning environment for the acquisition of WP skills. (iii) the formation of mental state with the use of VR. Figure 1 presents the conceptual framework of the study. This study proposes a VR learning approach for teaching WP to autistic children as its conclusion.

Figure 1- Conceptual Framework



Research Objectives

The aims of this study are to:

- Determine the word problem-solving abilities of autistic children;
- Identify ways a virtual reality environment can be integrated into the word problem-solving learning process; and
- Propose conceptual framework for teaching autistic children word problem comprehension using VR technology.

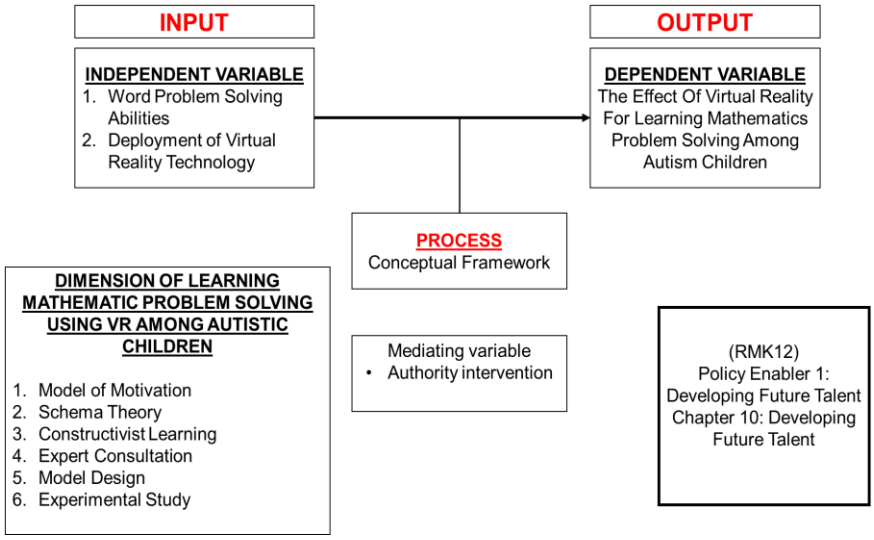
Conceptual Framework, Research Questions and Hypothesis

Conceptual Framework

In the course of creating the research objectives, a preliminary investigation will be done. The study's analyses support the definition of

difficulties and the research's primary objective. At this phase, a comprehensive grasp of the mathematics word problem-solving acquisitions of autistic youngsters will be attained. The purpose of the study is to investigate the incorporation of virtual reality application technology into the mathematics word problem-solving learning process as part of a treatment that will facilitate the formation of problem schemas among children.

Figure 2- The conceptual framework used in the study

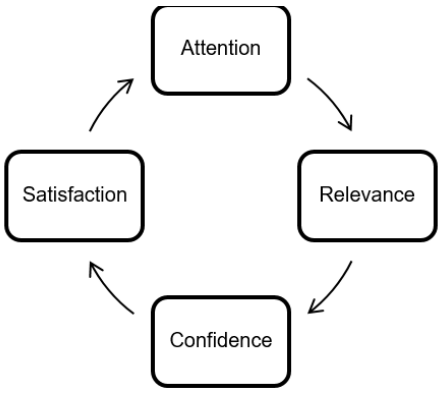


A. Theoretical Research

i. The Motivation Model

This proposed project utilises Keller's ARCS Model of Instructional Design, which defines four components to improve learning motivation. Attention (A), relevancy (R), confidence (C), and contentment are the factors (S). Figure 3 depicts the advantages of VR in constructing situation models.

Figure 3- ARCS Model



ii. The Theory of Schemas

Schema-induction theory, first introduced by Kochen et al.; (1983), describes the process by which individuals learn about new concepts by inducing a general schema from their prior knowledge of specific concepts. Schema theory is useful because it provides a framework for constructing problem-solving "schemas," which can be done inductively from previous experiences with a variety of specific cases. According to the research, children who have developed more comprehensive schemas are better able to make associations between new and old difficulties, and as a result, they will know when to use tried-and-true ways for finding answers [47].

iii. Constructivist Learning

According to constructivist theory, an effective learning process involves active participation in, and introspection upon, real-world experiences. The use of virtual reality in education places a premium on student participation. In addition, the constructivist theory mentioned by Dickey; (2005) as cited in [48] can have an impact on improving the VR learning environment.

B. Expert Consultation

Professional consultations with teachers and educators in the field of autism will be done to gather data for this purpose. The primary goal of this exercise is to map out the steps and components of learning how to solve mathematical word problems.

C. Model Design

To verify and assess the efficacy of the suggested design for issue schema formation in autistic children through the use of a VR application, a conceptual model will be built. Children will use this prototype to help them learn how to solve mathematical problems.

D. Experimental Study

The proposed design guideline model can be validated with the help of an experimental research conducted on a real-world project to evaluate the feasibility aspect. In order to get accurate test results from children, we'll be using problem-solving workbooks and a multiple-probe, across-participants design. Assessment will take held at the Malaysian Autism Society.

Research Questions

The questions to structure the study analysis are as follows:

- What are the word problem-solving abilities among autistic children; and

- How virtual reality environment can be integrated with the word problem-solving learning process.

Hypothesis

This study uses a qualitative approach when testing presumptions based on the influence of the factors studied. The five (5) variables under consideration—model of motivation, schema theory, constructivist learning, expert consultation, model design, experimental study—were assessed by the effect among the variables. The research hypotheses can be described in the following way:

H_1 = Virtual reality can facilitate development of accurate situation models

H_2 = Virtual reality can be used in generating mental representation

H_3 = Virtual reality can enhance reading comprehension

Discussion of Findings

The goal of this proposed study is to determine whether virtual reality may enhance the precision with which problem circumstances are formulated and the ease with which word problems are comprehended.

The researcher hypothesises that virtual reality can facilitate the development of accurate situation models, thereby enhancing reading comprehension, due to the positive effects of visual supports on the development of situation models and the perceived affordances of virtual reality in generating mental representations.

Significance of the Proposed Research

The significance of the study lies in its contribution of strategic solutions that will assist the researcher in broadening the scope of her investigation into the applicability of interactive media to the education of students with special needs. This discovery will mark a big advance in aiding students with autism and similar issues. This framework is intended to serve as a point of departure for educators, facilitators, and curriculum designers to develop effective tools and pedagogical strategies for enabling a marginalised group to overcome learning disability. The completion of this project will expand the range of technologies suited to the education sector and strengthen the researcher's research field in computer technology.

Conclusion

Children with autism spectrum disorder (ASD) would benefit from the application of virtual reality as an innovative learning technique to enhance accurate problem situation building and aid in word problem comprehension. The researcher hypothesises, based on the positive results that visual supports can contribute to the development of situation models and the perceived affordances of virtual reality in

generating mental representations, that the use of virtual reality can facilitate the development of accurate situation models, thereby enhancing reading comprehension.

A crucial measure of the efficacy of learning and teaching delivery in Malaysia is the stringent monitoring of stakeholder participation, particularly in connection to autistic student experience satisfaction and quality of life. Making sense of the deployment of VR technology to autistic children and stakeholders would encourage more support and involvement to create a win-win situation that would promote a conducive learning ecosystem, improve student learning outcomes, and leverage emerging technology to develop talent that is future-ready. Incorporating the model of motivation, schema theory, constructivist learning, expert consultation, model design, and experimental study, the Ministry of Education (MOE) plays a crucial role in the successful integration of VR application technology into the learning process for solving mathematics word problems among autistic children.

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