UNIVERSITI TEKNIKAL MALAYSIA MELAKA

VIRTUAL REALITY MODEL OF MATHEMATICAL WORDS PROBLEM FOR AUTISTIC CHILDREN

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A thesis submitted
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DECLARATION

I declare that this thesis entitled “Virtual Reality Model of Mathematical Word Problems For Autistic Children” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree..

Signature :.....

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Date : 02/07/2025

APPROVAL

I hereby declare that I have read this thesis and, in my opinion, this thesis is sufficient in terms of scope and quality for the award of Doctor Philosophy.

Signature : .....

Supervisor Name : PROF. TS. DR FAAIZAH BINTI SHAHBODIN

Date : 02/07/2025

DEDICATION

This thesis is dedicated with deepest gratitude to Allah, for His endless guidance and blessings throughout this journey.

To my beloved father, whose strength and prayers have always been a source of inspiration.

To my sons, Farhan, Fahmi, and Faris for being my greatest motivation and joy.

In loving memory of Musanif, whose presence is felt in every step of this journey.

To my respected supervisor, for their invaluable guidance, encouragement, and unwavering support throughout this research.

And to my dear friends, for their continuous motivation, understanding, and companionship during this research.

ABSTRACT

This research addresses the challenge of enhancing contextual knowledge and problem-solving abilities in everyday mathematics activities among autistic children. The study developed and evaluated the effectiveness of a Virtual Reality Model (VRMath), which integrates relevant learning theories and multimedia principles to provide an interactive learning experience. The primary objective is to investigate the impact of VRMath on learners' contextual knowledge, mental representation, and problem-solving skills. A mixed-methods design was employed, combining quantitative and qualitative approaches. The quantitative component utilized a single-subject research design, while the qualitative component included semi-structured interviews and participant observation. Three autistic children, aged 9 to 10 years, were purposefully sampled based on their ASD profiles and received individualized instruction over three months. The findings indicate that VRMath significantly improved the participants' contextual knowledge and problem-solving abilities. The main contribution of this research lies in demonstrating the potential of virtual reality as an effective educational tool for autistic children, thereby contributing to the Body of Knowledge (BOK) in special education and educational technology. This study provides valuable insights for educators and researchers seeking innovative methods to support the learning needs of autistic students.

MODEL REALITI MAYA UNTUK MASALAH PERKATAAN MATEMATIK DIKALANGAN KANAK-KANAK AUTISTIK

ABSTRAK

Penyelidikan ini menangani cabaran meningkatkan pengetahuan kontekstual dan kebolehan menyelesaikan masalah dalam aktiviti matematik harian di kalangan kanak-kanak autistik. Kajian ini membangunkan dan menilai keberkesanan Model Realiti Maya (VRMath), yang mengintegrasikan teori pembelajaran yang relevan dan prinsip multimedia untuk menyediakan pengalaman pembelajaran interaktif. Objektif utama adalah untuk mengkaji kesan VRMath terhadap pengetahuan kontekstual, representasi mental, dan kemahiran menyelesaikan masalah pelajar. Pendekatan penyelidikan yang digunakan dalam kajian ini menggabungkan kaedah kuantitatif dan kualitatif. Komponen kuantitatif menggunakan reka bentuk penyelidikan subjek tunggal, manakala komponen kualitatif melibatkan temu bual separa berstruktur dan pemerhatian peserta. Tiga kanak-kanak autistik, berumur 9 hingga 10 tahun, dipilih secara sengaja berdasarkan profil ASD mereka dan menerima pengajaran individu selama tiga bulan. Dapatan kajian menunjukkan bahawa VRMath secara signifikan meningkatkan pengetahuan kontekstual dan kebolehan menyelesaikan masalah peserta. Sumbangan utama penyelidikan ini adalah dalam menunjukkan potensi realiti maya sebagai alat pendidikan yang berkesan untuk kanak-kanak autistik, dengan itu menyumbang kepada Badan Pengetahuan (BOK) dalam pendidikan khas dan teknologi pendidikan. Kajian ini memberikan pandangan berharga untuk pendidik dan penyelidik yang mencari kaedah inovatif untuk menyokong keperluan pembelajaran pelajar autistik.

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LIST OF ABBREVIATIONS

AAC	-	Augmentative and Alternative Communication
ABA	-	Applied Behavior Analysis
ADHD	-	Attention Deficit Hyperactivity Disorder
AR	-	Augmented Reality
ASD	-	Autism Spectrum Disorder
CTML	-	Cognitive Theory of Multimedia Learning
EF	-	Executive Functioning
HMD	-	Head-Mounted Display
IEP	-	Individualized Education Plan
IQ	-	Intelligence Quotient
LINUS	-	Literacy and Numeracy Screening
MR	-	Mixed Reality
PND	-	Percentage of Non-Overlapping Data
SSRD	-	Single-Subject Research Design
UI	-	User Interface
UTeM	-	Universiti Teknikal Malaysia Melaka
VR	-	Virtual Reality
VRMath	-	Virtual Reality Mathematics Model

LIST OF APPENDICES

LIST OF PUBLICATIONS

The followings are the list of publications related to the work on this thesis:

Rosli, Z., Shahbodin, F., and Che Ku Nuraini C. K. M, 2023. Constructing A Conceptual Framework For Implementing Assistive Learning Technology To Enhance Word Problem Solving Skills In Children With Autism. Scandinavian Journal of Information Systems, 35(3), pp.326-333 (SCOPUS indexed).

Rosli, Z., Shahbodin, F., Yuwono, J., Gunarhadi, G., Yusuf, M., and Supratiwi, M., 2023. The Proposed Conceptual Framework to Enhance Mathematics Abilities on Children with Autism Spectrum Disorder (ASD) Through the Application of Virtual Reality Technology. Journal of Namibian Studies, 2(34), pp.1507–1520.

Rosli, Z., Shahbodin, F., and Che Ku Nuraini Che Ku Mohd., 2019. A Proposed Conceptual Framework of Word Problem Comprehension using Virtual Reality for Children with Autism. Advances in Social Science, Education and Humanities Research, 388, pp.316–321.

Rosli, Z., and Shahbodin, F., 2018 . Integrating Mathematics Problem Solving Process: A Virtual Reality Learning Approach. 5th LIS Liga Ilmu Serantau 2018, pp.12–23.

Rosli, Z., and Shahbodin, F., 2018. A Conceptual Framework Study of Learning Mathematic Word Problem Solving using Virtual Reality Environment for Children with Autism. Proceedings of Innovative Teaching and Learning Research Day 2018, Malacca, Malaysia, August 2018, UTEM.

CHAPTER 1

INTRODUCTION

1.1 Background

Autism spectrum disorder (ASD) affects approximately 1 in 54 children in the United States, making it one of the most prevalent developmental disorders (Maenner et al., 2020; Salari et al., 2022). It is characterized by impairments in social communication and interaction, along with the presence of restricted and repetitive behaviors (American Psychiatric Association, 2013). The population of students with ASD is diverse, with varying degrees of cognitive abilities, language skills, and sensory sensitivities (Maenner et al., 2020; Tan and Poon, 2022; Vogindroukas et al., 2022). This heterogeneity necessitates personalized and individualized approaches to education.

Students with ASD exhibit a unique learning profile characterized by strengths and challenges. While some individuals may have exceptional abilities in specific areas, such as pattern recognition or attention to detail, they often face difficulties in social communication, executive functioning, and cognitive flexibility (Kong, 2015; AlSalehi and Alhifthy, 2020). These challenges can impact various aspects of learning, including academic performance, problem-solving skills, and generalization of knowledge.

Academically, students with ASD may experience challenges in various subjects, including mathematics (Polotskaia and Savard, 2018; Wu, 2022; Polo-Blanco et al., 2024). They often exhibit difficulties in mathematical reasoning, problem-solving, and generalizing mathematical concepts. Word problem learning, in particular, poses challenges for students with ASD as it requires the application of mathematical concepts in real-life situations (Aziz

and Ahmad, 2015; Haghverdi and Wiest, 2016; Cox and Root, 2018). Difficulties in understanding word problems, extracting relevant information, and formulating solution plans can impede their mathematical problem-solving abilities. Additionally, students with ASD may struggle with reading comprehension, identifying key mathematical concepts, and comprehending contextual information within word problems (Cox and Root, 2018; Delisio et al., 2018; Root et al., 2018).

Assistive technology, including virtual reality (VR), has emerged as a promising tool to support the learning and development of students with ASD. VR provides an immersive, interactive, and customizable learning environment that can cater to the specific needs and challenges of students with ASD (Newbutt et al., 2016, 2017; Zhang et al., 2022). VR interventions have been explored in various aspects of ASD intervention, such as social skills training and therapy (Marozau et al., no date; Sideraki and Drigas, 2023), but their potential in academic learning remains relatively unexplored.

The integration of virtual reality (VR) technology into academic instruction tailored for students diagnosed with autism spectrum disorder (ASD) shows considerable promise in addressing the unique educational hurdles they face. Through the creation of interactive simulations and visually stimulating representations, VR platforms amplify comprehension, problem-solving abilities, and the extrapolation of mathematical principles. By immersing learners in virtual environments that closely emulate real-life scenarios, VR facilitates a learning environment abundant in contextual richness and multisensory engagement (Parsons, 2016; Sideraki and Drigas, 2023). Consequently, VR technology stands poised to provide substantial support to students with ASD in comprehending and resolving mathematical word problems, offering a highly captivating and customized educational setting.

Understanding the learning profile, academic challenges, and the potential of assistive technology such as VR is essential for developing effective instructional approaches to support the learning of students with ASD. By addressing the unique needs of this population, educators and researchers can enhance their academic experiences, promote skill development, and foster independence in learning. Further research is needed to explore the effectiveness of VR interventions and optimize the use of assistive technology in math education for autistic children, paving the way for inclusive and effective learning environments. Therefore, based on the above issue, this study intends to identify the difficulties in learning mathematical word problems among ASD children and how to design and develop a learning model for mathematical word problems using a virtual reality learning environment (VRMath) to overcome word problems comprehension, performance, and problems among ASD children in Malaysia.

1.2 Problem Statement

Teaching mathematics to children with autism spectrum disorder (ASD) is a unique journey that requires tailored instructional methods. These students often encounter hurdles in mathematical reasoning, problem-solving, and applying mathematical concepts to different contexts. Research indicates that up to 60% of children with ASD struggle with various aspects of math, from basic arithmetic to more complex problem-solving tasks (Bae, 2017; Cox and Root, 2018; NeuroLaunch, 2024). Their challenges are further intensified by difficulties in reading comprehension and social interactions, which make understanding and solving word problems particularly tough (Delisio et al., 2018; Kalandadze et al., 2022; Vulchanova et al., 2023). Word problems are vital in math education because they connect