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NEEDS ANALYSIS FOR THE DEVELOPMENT OF AN AUGMENTED REALITY-BASED LEARNING MODULE ON ISOMETRIC TRANSFORMATION FOR MALAYSIAN FORM 2 STUDENTS

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Abstract*:* *Augmented reality (AR) has emerged as a promising educational technology, offering immersive and interactive learning experiences that enhance student engagement and support conceptual visualization. In the Malaysian Form 2 mathematics curriculum, isometric transformations which include translations, reflections, and rotations, are foundational yet conceptually challenging topics. Traditional instructional methods often fail to effectively assist students in visualizing and understanding these transformations, resulting in learning gaps and reduced motivation. The interactive nature of AR holds potential to address these issues by enabling real-time visualization of transformations, thereby improving students' spatial reasoning, academic performance, and motivation to learn. This study aimed to conduct a comprehensive needs analysis to inform the development of an AR-based learning module focused on isometric transformations for Malaysian Form 2 students. A qualitative research approach was employed, involving structured interviews with five mathematics education experts from five different Malaysian states. Interview data were analyzed thematically, with transcripts coded and categorized into key themes. The findings revealed that isometric transformations, particularly those in the Form 2 syllabus, are essential for students' mathematical development. Experts unanimously agreed that integrating AR technology into learning modules offers significant pedagogical value for teaching this topic. Furthermore, they emphasized that the module's design should align with classroom teaching practices, including notes and activities. These insights provide a valuable foundation for developing an effective and contextually relevant AR-based instructional module.*

Keywords*:* *augmented reality, isometric transformation, module development, spatial visualization, motivation*

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Introduction

The twenty-first century has witnessed the profound impact of technology on teaching and learning, introducing both new challenges and opportunities for educators. The rapid advancement of technology within the education system plays a pivotal role in enhancing mathematics teaching and learning (Ministry of Education Malaysia, 2016). Integrating technology into schools offers several advantages, including the enhancement of critical and creative thinking, the development of multidimensional 21st-century skills, and improved academic performance (Yılmaz, 2021).

Technology also enables immersive learning experiences through extended reality technologies such as augmented reality (AR), virtual reality, and mixed reality (Meccawy, 2022). Among these, AR has been particularly effective in supporting students with low spatial skills. Its integration into education enhances cognitive development, promotes 21st-century skills, and boosts academic achievement (Danakorn Nincarean et al., 2019). AR offers realistic and interactive experiences that assist students in comprehending complex concepts (Kamphuis et al., 2014) and contributes to increased motivation and achievement across various disciplines. It allows learners to explore and interact with three-dimensional objects, thereby making the learning experience more dynamic (Kamal & Junaini, 2019). Moreover, AR has been shown to positively influence student engagement in subjects such as chemistry (Whatoni & Sutrisno, 2022), and it supports interaction, creativity, and intuitive learning through animations and simulations (Grodotzki et al., 2023; Kang et al., 2023; Lionoa et al., 2021).

A module is a structured instructional program designed to achieve specific learning objectives (Yusop, 2013). According to Mohd Noah and Ahmad (2019), a module is a systematically organized teaching resource that addresses a particular topic to facilitate student learning. It outlines clear instructional goals and systematically organizes activities to achieve those goals (Mohd Noah & Ahmad, 2005; Milano & Ullius, 1998). Learning modules have been shown to improve student performance and motivation (Rahman et al., 2021). Mohd Noah and Ahmad (2019) classified modules into four categories: academic, training, motivational, and instructional. This study focuses on the development of an instructional module aimed at supporting autonomous learning among students.

Technological advancements have enabled the integration of digital tools into mathematics instruction. For example, Md Yunus et al. (2019) developed a geometry module using Geometer's Sketchpad, while Ramli et al. (2024) created a calculus module for matriculation students based on the flipped classroom approach. Suryani et al. (2020) designed a spatial module utilizing GeoGebra, and Bakar and Ismail (2020) assessed tutorial-based modules as a mathematics intervention, reporting positive outcomes. Halimah et al. (2022) implemented a probing-prompting model supported by a mathematics module, which enhanced students' motivation and learning outcomes. Similarly, Suyanti et al. (2021) developed a digital module based on Realistic Mathematics Education, proving its effectiveness in primary mathematics education. More recently, Nadzri et al. (2023) introduced the GEOMAR3 module, which incorporates AR to teach spatial concepts.

The integration of AR in instructional modules supports flexible learning tailored to students' individual learning preferences (Nadzri et al., 2023). Additionally, the use of teaching modules equipped with appropriate technologies along with sufficient teacher training can significantly improve the overall effectiveness of the learning process (Ismail & Daoh, 2021). Interactive and dynamic modules enhance conceptual understanding in an engaging manner, thus fostering

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greater motivation and academic success (Shamsudin & Surat, 2023). Prior studies consistently indicate the positive impact of modules on mathematics learning. Accordingly, the use of modular learning in mathematics is both meaningful and beneficial in enhancing student achievement and motivation in the classroom.

Problem Statement

The achievement levels of Malaysian students in Mathematics have become increasingly concerning (Ministry of Education Malaysia, 2020, 2022; Examination Board, 2022). According to the 2022 Sijil Pelajaran Malaysia (SPM) Examination Result Analysis Report, of the 373,974 candidates, 26.2% failed Mathematics and 24.3% failed Additional Mathematics marking the highest failure rates among the 95 subjects offered. These alarming statistics align with international assessments such as Trends in International Mathematics and Science Study (TIMSS) 2019 and Programme for International Student Assessment (PISA) 2022, where Malaysia fell short of the Ministry of Education's aspiration, as outlined in the Malaysia Education Blueprint 2013–2025, to be in the top one-third of participating countries (Ministry of Education Malaysia, 2013, 2020, 2022). In PISA 2022, Malaysia ranked 56th out of 81 countries, with only 41% of students attaining proficiency level 2 or above in Mathematics, compared to the OECD average of 69%. The declining trend in average scores since PISA 2018 highlights persistent challenges.

Similarly, TIMSS 2019 placed Malaysia in the bottom third, ranking 26th in Mathematics among 39 countries (Ministry of Education Malaysia, 2020). Performance in the Geometry domain a critical area in the curriculum has remained inconsistent and relatively weak. From 2007 to 2019, scores fluctuated with minimal improvement, and Malaysia ranked 26th out of 36 countries in 2019 (Ministry of Education Malaysia, 2020). This suggests a continuous struggle among students to comprehend geometric concepts (Winer & Battista, 2022; Nadzeri et al., 2022).

Geometry is a fundamental component of the mathematics curriculum, yet students often lack motivation and conceptual understanding due to the spatial visualization required (Serin, 2020; Shaimi et al., 2023). Isometric Transformations, taught in Form 2, include translation, reflection, and rotation concepts that many students find challenging. Studies show that learners struggle with memorization, conceptual understanding, and application-level problems in this topic (Adhikari & Subedi, 2021; Clements & Burns, 2000; Olson et al., 2020). A weak foundation in Form 2 impacts students' ability to grasp advanced concepts in Form 5, such as enlargement and the combination of transformations, which are crucial for the SPM. In TIMSS 2019, only 35.9% of Malaysian students correctly answered an Isometric Transformation question, compared to 67% in Singapore, 69% in South Korea, and 75% in Taiwan (Ministry of Education Malaysia, 2021). Furthermore, 59.4% of students answered incorrectly, while 4.8% skipped the question entirely. These figures reflect both low mastery and reduced confidence in the topic.

Students often encounter significant pedagogical challenges when learning isometric transformations, primarily due to limitations in spatial reasoning and difficulties in visualizing abstract geometric concepts. Traditional instructional methods, which rely heavily on static images and textbook-based exercises, frequently fail to engage learners or adequately support those with lower spatial abilities. These instructional shortcomings impede both conceptual understanding and procedural fluency. Augmented Reality (AR) presents a promising alternative by converting abstract concepts into interactive, three-dimensional experiences that

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can improve comprehension and retention. By offering real-time feedback and dynamic visualizations, AR effectively bridges the gap between theoretical understanding and practical application, while also enhancing student motivation through a more immersive, engaging, and accessible learning environment.

Students' low motivation and weak spatial visualization abilities further hinder their understanding of Isometric Transformations (Mohd Nasir et al., 2020). Past studies have found that students who enjoy Mathematics tend to perform better academically (Ministry of Education Malaysia, 2020). Therefore, interventions targeting both conceptual clarity and student engagement are needed.

Although various Mathematics modules have been developed, most do not integrate digital or immersive technologies. For example, Mokhtar et al. (2022) emphasized procedural and conceptual knowledge without incorporating technology. Similarly, modules by Ibrahim et al. (2019) and Marham et al. (2023) focused on higher-order thinking and problem generation, respectively, without digital integration. On the other hand, technology-enhanced modules such as those by Md Yunus et al. (2019), Suryani et al. (2020), and Ramli et al. (2024) utilized software like Geometer's Sketchpad and GeoGebra, but did not specifically focus on spatial visualization. While Nadzri et al. (2023) developed an augmented reality (AR) module on spatial topics, it did not target Isometric Transformations. Similarly, Pratamadita and Dwiningsih (2022) focused on spatial skills using interactive multimedia in Chemistry, not Mathematics.

Despite growing interest in AR-based learning tools, no existing study has developed an AR-integrated learning module specifically for teaching Isometric Transformations in Form 2 Mathematics, with a focused objective of enhancing students' spatial visualization skills. This represents a significant research gap that this study aims to address. Accordingly, this study aims to identify the need to develop a learning module that integrates Augmented Reality (AR) specifically for the topic of Isometric Transformations in Form 2 Mathematics, with a focus on enhancing students' spatial visualization skills. In summary, this study is significant as it responds to a pressing educational challenge by proposing an innovative and technology-driven solution. The development of an AR-based module has the potential to address students' difficulties in spatial reasoning, increase motivation, and ultimately improve learning outcomes in Geometry and thus contributing to national efforts to enhance Mathematics education quality in Malaysia.

Literature Review

Augmented Reality in Education

Previous studies have extensively documented the positive impact of Augmented Reality (AR) on education. Nor and Mokhtar (2021) demonstrated that AR enhances students' understanding and interest, while Poobalan and Mahmud (2022) highlighted its effectiveness in improving both teaching and learning processes. Additionally, research by Muhammad et al. (2021) found that AR increases student engagement, motivation, and learning outcomes. The ability of AR to allow students to visualize and interact with educational content significantly contributes to improved comprehension, as supported by Özçakır and Çakıroğlu (2022). This growing body of evidence suggests that AR is effective across various academic levels and disciplines, offering transformative potential by simulating and integrating complex processes into educational practice.

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However, the adoption of AR in education is not without challenges. Cevikbas et al. (2023) identified several limitations, including technical infrastructure issues, device and software constraints, and connectivity problems. Furthermore, prolonged screen exposure and the small screen size of some devices may pose health concerns and increase cognitive load due to the need to process dual-world information. The single-user mode of many AR applications also limits opportunities for social interaction, which remains a critical component of effective learning environments.

Augmented Reality for Spatial Visualization

Several studies have underscored the specific benefits of AR for spatial visualization, particularly within mathematics education. Danakorn Nincarean et al. (2019) reported positive effects of AR on spatial visualization skills, a finding corroborated by Hidajat (2023) and Hidayat et al. (2023), who noted improvements in both visualization skills and creative thinking. Angraini et al. (2022) emphasized that the interactive and immersive nature of AR, especially in mobile-based learning environments, further enhances these cognitive skills.

The importance of spatial visualization in mathematics is well established. For instance, Bull et al. (2008) identified a correlation between visual–spatial skills and both early counting abilities and overall mathematics performance. Supporting this, Sukestiyarno et al. (2023) explored ethnomathematical approaches in non-Euclidean geometry, while Szabó et al. (2023) found that the use of real-life tasks and innovative methods significantly improved spatial performance in preadolescents. Harris et al. (2023) investigated the relationship between spatial visualization and mathematics achievement, revealing that students with strong spatial abilities exhibited superior conceptual and procedural understanding in geometry and measurement tasks. Conversely, students with lower spatial skills often struggled, despite demonstrating adequate procedural knowledge.

Spatial Visualization in Geometry

Medina et al. (2024) emphasized the role of spatial visualization tools—such as virtual environments and 3D printing, in enhancing mathematical understanding. Their study demonstrated significant improvements in students' spatial visualization skills when such tools were used, compared to control groups. Similarly, Mix et al. (2020) confirmed that spatial skills training positively impacts mathematics performance among students in Grades 1 and 6.

Augmented Reality for Motivation

Augmented Reality (AR) has also been shown to improve student motivation and engagement (Agustika, 2021), as well as enhance spatial ability and learning outcomes (Lam et al., 2023). Integrating AR into educational settings enriches learning through contextualization, personalization, and real-object interaction (Sáez-López et al., 2020), all of which contribute to increased interest, motivation, satisfaction, and attention (Lim, 2022). Papakostas et al. (2021) further emphasized AR's potential in improving learners' spatial abilities across diverse educational settings, highlighting its transformative impact on geometry instruction.

Instructional Module Development

Substantial research supports the efficacy of learning modules in enhancing educational outcomes. Daroini and Alfiana (2022) emphasized their role in promoting independent learning, while Mubarok (2022) highlighted their adaptability to various educational contexts. Agusta (2022) underscored the benefits of contextual teaching and learning through modules. In line with this, Lestari (2021) advocated for teacher training in social media and flipped classroom

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strategies to support hybrid learning environments. Kamlin and Keong (2020) discussed the effectiveness of multimedia tools, such as video adaptations, within instructional modules.

The application of instructional modules has been linked to improved learning outcomes across multiple disciplines, including Chemistry (Aris et al., 2025), Mathematics (Basari & Siew, 2022), Science (Jumaat, 2022), Malay Language (Hassan et al., 2021), Entrepreneurship (Ahmad & Siew, 2022), History (Kaviza, 2021), and Physics (Dewi & Kuswanto, 2023). E-learning modules, in particular, support flexibility in teaching and learning regardless of time and location (Ismail & Kob, 2023). Moreover, learning modules are increasingly being integrated with technologies such as computational media (Siregar & Harahap, 2020), AR (Nadzri et al., 2023), and video adaptations (Kamlin & Keong, 2020). These technological integrations have significantly enhanced student performance, motivation, and skill development.

Overall, research indicates that learning modules, whether gamified, digital, or AR-assisted, can effectively enhance student achievement, promote higher-order thinking skills, and improve pedagogical outcomes. For example, integrating AR into modules on isometric transformations has been shown to foster critical thinking (Nadarajan et al., 2023), create effective learning scenarios, and deepen students' understanding of complex mathematical concepts (Sáez-López et al., 2020). Additionally, visual training involving AR has been associated with more meaningful learning and increased motivation (Lau et al., 2021).

Summary of Literature Review

As summarized in Table 1, extensive literature supports the integration of Augmented Reality in education, particularly in enhancing student engagement, spatial visualization, and academic performance in mathematics. AR has demonstrated effectiveness in facilitating the comprehension of complex concepts, motivating learners, and fostering higher-order thinking. Similarly, instructional modules especially those incorporating digital or AR elements have proven beneficial across various subjects and educational contexts. Despite these promising findings, gaps remain in the practical implementation of AR-based learning modules specifically tailored to the teaching of isometric transformations in mathematics. Most existing studies focus on either AR or learning modules in isolation, with limited research exploring the combined effects of AR-integrated instructional modules on spatial reasoning and conceptual mastery among lower secondary students. Therefore, this study aims to bridge this gap by developing and evaluating an AR-enhanced instructional module for isometric transformations, providing evidence-based insights to improve pedagogical practices in mathematics education.

Table 1: Summary of Prior Studies on AR and Instructional Module Development.

Study/Author(s)	Focus	Subject/Discipline	Main Outcomes
Nor & Mokhtar (2021); Poobalan & Mahmud (2022)	General impact of AR on learning	General Education	Improved understanding, teaching effectiveness, and student interest
Muhammad et al. (2021); Özçakır & Çakıroğlu (2022)	AR for engagement and interaction	General Education	Increased motivation, engagement, and comprehension
Danakorn Nincarean et al. (2019); Angraini et al. (2022)	AR for spatial visualization skills	Mathematics	Improved spatial skills and geometric reasoning

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Hidayat et al. (2023); Hidajat (2023)	AR for visualization and creativity	Mathematics	Enhanced visualization and creative thinking
Harris et al. (2023); Bull et al. (2008)	Spatial ability and math achievement	Geometry, Measurement	High spatial ability linked to better conceptual and procedural math performance
Medina Herrera et al. (2024); Mix et al. (2020)	Spatial tools (VR/3D printing)	Geometry/General Mathematics	Significantly improved spatial reasoning in treated groups
Agustika (2021); Lam et al. (2023); Lim (2022)	AR for student motivation	Mathematics/General	Boosted attention, satisfaction, and academic motivation
Papakostas et al. (2021); Sáez-López et al. (2020)	AR for contextualized learning	Geometry/General Education	Real-object interaction, deeper understanding, personalized learning
Daroini & Alfiana (2022); Mubarok (2022)	General benefits of instructional modules	General Education	Supported independent and contextual learning
Agusta (2022); Lestari (2021)	Modules in hybrid/flipped learning	Social Studies, Multidisciplinary	Enabled flexible teaching and integration of digital tools
Kamlin & Keong (2020); Siregar & Harahap (2020)	Multimedia/e-modules in education	Cross-curricular	Enhanced engagement and flexible access
Dewi & Kuswanto (2023); Aris et al. (2025)	AR-integrated modules	Physics, Chemistry	Improved critical thinking, communication, and learning interest
Basari & Siew (2022); Ahmad & Siew (2022)	Modules for academic achievement	Mathematics, Entrepreneurship	Significant gains in test scores and student performance
Nadzri et al. (2023); Nadarajan et al. (2023)	AR modules for geometry & HOTS	Mathematics (Primary & Secondary)	Boosted higher-order thinking skills and performance in geometric transformation
Lau et al. (2021)	Visual training with AR	Mathematics	Deeper learning and increased student motivation

Method

This study employed a qualitative research design using semi-structured interviews (appendix A) with expert Mathematics teachers to gather in-depth insights into the challenges of teaching isometric transformations and to obtain expert recommendations for the development of an Augmented Reality (AR)-integrated learning module for Form 2 students in Malaysia. The interview protocol was designed to explore the effectiveness of existing teaching aids and to identify pedagogical requirements for enhancing students' conceptual understanding of abstract mathematical content.

The target population comprised expert Mathematics teachers with over ten years of teaching experience. According to Melnick and Meister (2008), this level of experience qualifies them as veteran educators. Their extensive instructional backgrounds and pedagogical insights make them particularly well-positioned to evaluate innovative educational technologies. Moreover, evidence suggests that experienced teachers demonstrate greater effectiveness in delivering STEM content compared to their less experienced counterparts (Jekri & Han, 2020). Purposive sampling was employed to select participants with relevant expertise and deep familiarity with the research topic. As noted by Creswell and Poth (2018), purposive sampling ensures the selection of individuals who are especially knowledgeable about the phenomenon under investigation. A total of five expert Mathematics teachers (coded as PK1 to PK5), each from a different Malaysian state, were selected. Sampling continued until data saturation was achieved,

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as recommended by Creswell (2012), who asserts that qualitative saturation typically occurs with 3 to 10 participants.

Table 2: Participant Profiles

Study Participant	Gender	School Type	School Area	State	Selection Criteria
PK1	Female	National Sports Secondary School	Urban	Terengganu	Expert Mathematics teacher
PK2	Female	National Secondary School	Rural	Perak	Expert Mathematics teacher
PK3	Male	National Secondary School	Rural	Kedah	Expert Mathematics teacher
PK4	Female	National Secondary School	Urban	Negeri Sembilan	Expert Mathematics teacher
PK5	Male	National Secondary School	Urban	Malacca	Expert Mathematics teacher

The researcher served as the primary instrument for data collection. An interview protocol was developed and reviewed by a qualitative research expert to ensure clarity, alignment with research objectives, and appropriateness of content. Participants were contacted via Telegram and briefed on the study's objectives, procedures, and ethical safeguards. Those who agreed to participate were informed of the interview arrangements and provided informed consent. Interviews were conducted either in person or virtually, depending on participants' availability. All sessions were audio-recorded using a portable recording device and subsequently transcribed verbatim. Participants were given the opportunity to review and verify their transcripts to ensure accuracy, thereby strengthening the credibility and trustworthiness of the data through member-checking.

The interview protocol underwent expert validation and its reliability was assessed using Cohen's Kappa coefficient, yielding a value of k = 1.00, indicating near-perfect agreement (Cohen, 1960). To further enhance reliability, participants reviewed and authenticated the final transcripts, following the procedural guidance of Bogdan and Biklen (2007). This validation process helped ensure that the data accurately reflected the participants' responses.

An inductive thematic analysis was conducted, following the six-phase framework established by Braun and Clarke (2019). The analysis process included: (1) familiarisation with the data through transcription and repeated reading, (2) generation of initial codes, (3) identification of potential themes, (4) review and refinement of themes, (5) defining and naming of final themes, and (6) producing the final narrative. Microsoft Word was used as a tool to manage and organise the qualitative data. This inductive approach, as advocated by Clarke et al. (2015), enabled the researcher to derive themes directly from the data rather than applying preconceived theoretical frameworks. The identified themes were later used to inform the design and development of the AR-integrated learning module, ensuring that it addressed the real needs and pedagogical insights of experienced educators.

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Ethical principles were strictly observed throughout the study, following the guidelines recommended by Merriam and Tisdell (2015). Participants were informed about the research purpose, procedures, potential risks, and benefits. Informed consent was obtained prior to data collection, and participants were made aware of their right to withdraw at any time without penalty. To maintain confidentiality, participants' real names were not disclosed. Instead, codes (PK1 to PK5) were assigned to anonymise responses. All data were securely stored and restricted to authorised personnel only. Interview questions were carefully designed to avoid psychological discomfort, and no personally sensitive information was requested. The interview protocol was also reviewed and approved by the university's ethics committee to ensure adherence to institutional ethical standards. All collected data including audio recordings and transcripts were handled in a manner that ensured privacy, confidentiality, and data protection. By observing these ethical safeguards, the study ensured the protection of participant rights and upheld the validity and integrity of the research findings.

Result and Discussion

Four themes have been identified from the objective analysis of the study.

Theme (i): Topics that need attention in Form 2 Mathematics

The Mathematics DSKP for Form 2 outlines 13 topics across five learning areas: Numbers and Operations, Measurement and Geometry, Relations and Algebra, and Statistics and Probability. Within Measurement and Geometry, key issues include Polygons, Circles, Three-Dimensional Geometric Shapes, and Isometric Transformations.

During the interview sessions, two codes emerged: (1) Important topics and (2) Difficult topics. Isometric Transformation was identified as crucial for students, as it prepares them for combining transformation types in the Form 5 Sijil Pelajaran Malaysia (SPM) examinations. All four experts underscored its importance, highlighting its relevance at the upper-secondary level. However, one expert also classified it as problematic, suggesting that students face significant challenges in mastering it.

Code 1a: Important topics
PK1 highlights the continuity between Form 2 content and SPM (Form 5). PK1 observes that isometric transformations are not part of the Form 3 and 4 syllabi but reappear in Form 5, where they are tested in more complex combinations. The teaching strategy in Form 2 is to teach each transformation separately, allowing students to focus on one concept at a time. However, in the SPM exam, students are expected to solve questions that combine two or three transformation types in a single problem. This shows how a foundational understanding of these topics in Form 2 becomes essential for tackling more challenging SPM questions later.

> *…So, Form 2, which I see, has some topics related to SPM topics. For example, the transformation has translation, reflection, and rotation. So, those things are not in the syllabus for Form 3 and 4. However, Form 5 has questions related to Form 2. The only difference is that during Form 2, they learn separately, i.e., one by one, right? Another translation, another reflection, another rotation. But when SPM combines 2 or 3 types of transformation to solve one question…(Int-PK1)*

PK2 emphasizes that Isometric Transformation is a key topic that students must comprehend before progressing to higher levels. The connection to SPM is critical, as failure to grasp this topic could result in difficulties later. PK2 expresses concern that if students don't fully

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understand the subject by the time they approach SPM, it will be challenging for them to succeed.

> *...This topic is also important for students and needs to be understood by students before they go to the next level. People want the ending close to SPM. If they don't understand, it's hard...(Int-PK2)*

PK3 shares the results of mapping lower secondary school topics crucial for upper secondary education. They emphasize the need to master certain Form 2 topics to be prepared for upper secondary school and the SPM exam. For example, Chapter 11, Isometric Transformation, is directly relevant to upper secondary transformation topics. This analysis highlights the importance of building a solid foundation in these Form 2 subjects. Educators and curriculum planners should prioritize these areas to better prepare students for advanced studies and exams.

> *...Actually, if we study, I have made one we call it mapping. I have been involved with my State Education Department to map the topics of Forms 1, 2, and 3, which have an impact or have a significant connection to upper secondary topics. Surprisingly, the Form 2 topics are most related to the upper secondary topics, which are Form 4 and Form 5. So, if we look at Form 2, we will see 13 topics. I can say that out of those 13 topics, one of the very important topics that students have to master before they sit down to enter upper secondary school for the first SPM is factoring and algebraic fractions, Chapter 2. Algebraic formulas, Chapter 3. Polygons and Circles, Chapter 4 and Chapter 5. Coordinates, Chapter 7. These coordinates are important to answer the title of transformation, the title of what is the name of scattering, and the boy wants to plot, and so on. Then, velocity and acceleration in Chapter 9, the slope of a straight line in Chapter 10, Isometric Transformation in Chapter 11, the measure of central tendency in Chapter 12, and simple probability in Chapter 13. So basically, if I have 13 topics, I can reject only 1 or 2 topics. The rest are all important...(Int-PK3)*

Like PK2, PK5 also stresses the significance of Isometric Transformation as a critical topic that must be mastered in preparation for SPM. PK5 emphasizes that understanding this topic in Form 2 is necessary to build a foundation for more advanced topics later.

> *...This topic is important. Students need to master it in preparation for SPM...(Int-PK5)*

Code 1b: Difficult topic

PK4 points out that weaker students often struggle with finding the center of rotation when rotating an object by 90 degrees and subsequently drawing the image. This difficulty highlights a standard stumbling block in the rotation sub-topic of Isometric Transformations.

> *...Another one, if you want to emphasize it, can also be the topic of isometric transformation, especially rotation. Students are weak in determining the center of rotation of 90 degrees and drawing the image...(Int-PK4)*

The interview findings underscore the significance of Isometric Transformations in preparing students for upper secondary education and the SPM exam. While these topics are crucial, they can also be challenging, necessitating focused attention from educators to ensure students build a solid foundational understanding.

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Theme (ii): Need for Technology-Based Teaching Aid

The second theme of the study centers on the necessity of incorporating technology-based teaching aids to enhance learning experiences. This theme underscores integrating technology, particularly smartphones, into educational methods to improve accessibility, engagement, and effectiveness. The codes within this theme explore various aspects of leveraging technology as a teaching tool, focusing on disseminating additional information, providing supplementary activities at home, enhancing teaching effectiveness, and increasing student motivation.

Code 2a: Additional information is needed through smartphone dissemination methods

PK1 suggests that incorporating mobile phone applications can be beneficial for disseminating extra information to students, making learning more accessible and efficient.

> *...If there is an additional application that uses mobile phones, that's a good idea. It helps...(Int-PK1)*

Code 2b: Additional activities at home

PK1 emphasizes that providing students with applications they can use at home allows them to engage in additional activities, reinforcing their learning outside the classroom.

> *...So, extra time at home using the provided application is very helpful...(Int-PK1)*

Code 2c: Application use increases effectiveness

PK2 mentions that the applications can enhance student achievement by aiding their understanding.

> *...So, when achievement is the application, it becomes a tool for us to give the student an understanding of what to learn. It's just that we can't get students interested in using the application. So, my study was not successful. It has failed to attract students' interest. Only we can improve the achievement...(Int-PK2)*

PK3 finds smartphones, when used appropriately, can significantly improve teaching effectiveness.

> *...Yes, for me it is very suitable. Using a smartphone, but under control... (Int-PK3)*

PK5 supports the idea that integrating smartphones is an effective way to enhance teaching and learning outcomes.

> *...Smartphone integration is ideal for improving teaching effectiveness...(Int-PK5)*

Code 2d: Application use increases motivation

PK3 notes that teachers need to use technology in their teaching methods to keep up with the technological environment students are accustomed to.

> *...Teachers may need to integrate technology into teaching. That's the first thing because there is a lot of technology use...(Int-PK3)*

PK4 states that adapting teaching methods to include technology must align with the current generation's familiarity and comfort with technology.

> *...The technology generation is growing, so it may be necessary to use technology as well...(Int-PK4)*

PK5 argues that using smartphones in teaching can increase students' motivation and interest in subjects like mathematics by making learning more engaging and relatable.

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> *...Learning methods should change. This is our generation, right? Lots of technology. So teaching can't be the old way either. We have to use technology too. Just close to them. Smartphones are a tool that can provide attractiveness in learning mathematics...(Int-PK5)*

The theme underscores the need for technology-based teaching aids, mainly through smartphones. Codes 2a and 2b highlight the benefits of providing additional information and activities through smartphone applications, aiding in continuous learning at home. Code 2c emphasizes that smartphone applications can improve teaching effectiveness despite challenges in student engagement. Code 2d focuses on the motivational benefits of integrating technology, suggesting that technology use aligns with the current generation's habits and can make learning more appealing. Overall, integrating smartphones in education is a crucial step towards enhancing both the effectiveness and appeal of teaching methods.

Theme (iii): Proposed Module Features

This theme revolves around the essential features for developing a practical educational module. The codes discuss various elements the module should include to enhance student learning and engagement.

Code 3a: Notes

PK3 emphasizes that the inclusion of detailed notes in the module is crucial. These notes should support the interactive aspects of the learning process, helping students understand the topics thoroughly.

> *...If there is a module, I will add it to the first note. You have to have a note...(Int-PK3)*

Code 3b: Learn interactively

PK3 stresses that interactive learning is essential for student engagement. The module should include features allowing students to interact dynamically with the content, making the learning process more engaging and effective.

> *...If there is a module, I will add it to the first note. You have to have a note. Most importantly, the apps want to help students learn to understand the topic interactively...(Int-PK3)*

Code 3c: Exploration activities

PK1 suggests creating activities that encourage exploration and hands-on practice is vital. They help students understand complex concepts by combining different transformations, allowing them to draw conclusions and reinforce learning.

> *...Maybe create an activity, and we combine some of those transformations using modules that will be developed later...*
>
> *...How do we want to conclude? So, we make an activity based on what you want to provide. After that, students automatically revise from the beginning of the subtopic...(Int-PK1)*

PK2 emphasizes the need to incorporate activities and quizzes to ensure students can practice what they learn and receive immediate feedback on their understanding, enhancing the learning experience.

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> *...If we make a module that needs to be made, there should be an activity. From that activity, we run a quiz...(Int-PK2)*

PK4 highlights that exploration activities within the module should cover different aspects of transformations, providing students with a comprehensive understanding of the topic.

> *...If the transformation is the same, students can explore many parts of the activity...(Int-PK4)*

Code 3d: Evaluation
PK2 states that regular evaluation after activities is essential to measure student progress. Assessments help identify areas where students may need additional support or practice.

> *...We evaluate after the activity is done. So, activity with assessment...(Int-PK2)*

The proposed features for the educational module emphasize the importance of interactive learning, detailed notes, exploration activities, and regular evaluation. Including notes aids comprehension, while interactive elements engage students more effectively. Exploration activities enable hands-on learning and practical application of concepts, and regular assessments help track student progress and understanding. Together, these features create a comprehensive and effective learning tool.

Theme (iv): Proposed Technology Features

This theme focuses on the technological elements that should be incorporated into the educational module to enhance learning. The codes discuss various features and their benefits in improving student comprehension and engagement.

Code 4a: Helps visualization
PK2 emphasizes the importance of 3D and AR for visualization. Notes that AR helps students see and interact with objects in a way that aids memory and understanding. Compared to tangible items, AR repeatedly exposes students to visual information, enhancing cognitive retention.

> *...If we make it in 3D form, especially AR, because I see this AR even when we make it in 3D form and bring it into the student class. Can you see the thing moving? Like I did before, we move, we have the material. So, if a student is focused on AR and so on, technology is close to the front, and then he can imagine that thing in his mind by using cognitive and so on, right? We use cognitive theory there, right? So, he repeatedly looks at that thing to remember and memorize it. So, compared to me, I make tangible items first because students don't memorize them when we make tangible items. They are the ones who use them...(Int-PK2)*

PK3 shares an example of how AR technology can make abstract concepts more concrete and understandable by providing clear, interactive visualizations. This helps students grasp difficult topics more quickly.

> *...Very suitable. I have seen one of my friends, my friend Teacher X, once make an AR for the title of the plan and elevation. See how AR helps students to see more clearly. How can the picture be drawn?...(Int-PK3)*

Code 4b: Augmented reality integration
PK2 highlighted the benefits of Augmented Reality (AR) in making lessons more engaging and memorable. Integrating AR into the instructional module offers an immersive learning

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experience that captures students' attention. This technology aligns with cognitive theory, enhancing memory retention and conceptual understanding through repeated visual exposure.

> *…If we present it in 3D form, it's even more effective with AR. When we bring this into the classroom, students can actually see the object in motion. Like what I've done before we move the object, we have the content, and if a student is focused on the AR, they can visualize it in their mind. That's where cognitive theory comes in, right? When they repeatedly view the object, it helps them remember and internalize it. I've tried using tangible items before, but students don't memorize as well when using physical objects. With AR, they're the ones interacting directly with the content…(Int – PK2)*

PK3 supports the use of AR, citing a colleague's successful implementation of AR in teaching. Notes that AR made complex concepts more apparent for students.

> *…Very suitable. I have seen one of my friends, Teacher X, once made an AR for the title of the plan and elevation. See how AR helps students to see more clearly. How can the picture be drawn?…(Int-PK3)*

Code 4c: Allow exploration activities
PK4 suggests that providing students with tools for exploration, such as Geogebra, encourages active learning. This hands-on approach helps students experiment and understand concepts deeply by exploring them independently.

> *…The transformation chapter is also very good when students can explore on their own using an application like Geogebra…(Int-PK4)*

Code 4d: Animated description
PK5 recommends using animation to describe processes within the teaching module. It helps students understand the dynamic aspects of mathematical concepts by visually showing the steps involved.

> *…The teaching module should emphasize the process. The processes that occur can be made in the form of animation…(Int-PK5)*

The proposed technology features for the educational module highlight the use of advanced visualization tools like 3D models and augmented reality (AR) to improve comprehension and engagement. These technologies make abstract concepts more concrete, aiding memory retention and understanding. Additionally, allowing students to explore ideas through applications and using animations to describe processes further enhances the learning experience by making it interactive and dynamic. These features collectively aim to create a more engaging and effective educational tool.

The study identified four key themes. Isometric Transformations emerged as critical and challenging, foundational in preparing students for more complex transformations in the Form 5 SPM exams. Experts emphasized the need for focused instruction in Form 2 to ensure students are well-prepared for these future challenges. Incorporating technology, particularly smartphones, was seen as essential. Mobile applications can provide additional learning resources and activities, enhance teaching effectiveness, and boost student motivation. Practical educational modules should include detailed notes, interactive learning elements, exploration activities, and regular evaluations. These features support comprehension, engagement, hands-on learning, and continuous assessment. Advanced visualization tools like 3D models and AR were highlighted for their ability to make abstract concepts more concrete. AR promotes active learning, while animations help illustrate dynamic processes, enhancing student understanding and engagement.

Conclusion

This study emphasizes the critical role of specific Form 2 Mathematics topics, particularly *Isometric Transformations*, in preparing students for upper secondary education and the SPM examinations. Through an in-depth analysis of expert interviews, four main themes were identified, highlighting both the significance and challenges of these topics, as well as the necessity for innovative teaching strategies. First, *Isometric Transformations* emerged as a foundational topic for students' success in higher-level mathematics. Experts noted that while students are introduced to transformations separately in Form 2, the SPM examination requires them to apply these concepts in more complex and integrated ways. This gap underscores the importance of mastering these foundational concepts to equip students for the demands of the upper-secondary curriculum. Second, the study underscores the need for technology-based teaching aids. Experts unanimously advocated for the integration of smartphones and other technological tools into the learning process. These tools enhance engagement and offer students the opportunity to reinforce their understanding through interactive applications. Although challenges remain in motivating students to utilize these applications, their potential to improve learning outcomes is evident. Third, the proposed features of an educational module highlight essential components for effective teaching and learning. Incorporating detailed notes, interactive learning activities, and regular evaluations can provide a comprehensive educational experience that supports deeper understanding and retention. The experts stressed the value of exploration-based and hands-on activities, reinforcing the importance of dynamic and student-centered teaching approaches. Lastly, the proposed technological features for the educational module such as augmented reality (AR) and 3D visualization tools demonstrate promising potential for enhancing student comprehension and engagement. These technologies help students visualize complex concepts more tangibly, thereby supporting memory retention and making learning more impactful and relatable.

Based on these findings, the following actions are recommended:

1) Curriculum enhancement through technology: Stakeholders should invest in the development and integration of technology-based teaching aids, including mobile applications and AR tools, into the mathematics curriculum especially for *Isometric Transformations*. Professional development programs should also be implemented to train teachers in the effective use of these technologies in classroom settings.
2) Module development: It is crucial to develop comprehensive learning modules that feature detailed instructional notes, interactive tasks, and regular assessments. These modules should be designed to engage students and reinforce their conceptual understanding, particularly for abstract or complex topics.
3) Student motivation strategies: Teachers should adopt varied approaches to encourage the use of technology-based learning tools. These may include exploration activities, collaborative projects involving technology, and incentives for engaging with supplementary learning applications.

Future studies should further investigate the core components necessary for designing and developing AR-integrated learning modules to enhance the teaching and learning of practical mathematical skills particularly *Isometric Transformations*. There is a pressing need to produce contextually relevant AR-integrated modules tailored for Form 2 Mathematics in Malaysia, offering a viable and effective alternative to traditional instructional methods.

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Appendix A

INTERVIEW PROTOCOL FOR NEEDS ANALYSIS STUDY ON DEVELOPMENT OF ISOMETRIC TRANSFORMATION MODULE WITH AUGMENTED REALITY IN SECONDARY SCHOOL MATHEMATICS EDUCATION

Purpose

The purpose of this interview protocol is to serve as a guide for conducting interviews with several experts in the field of secondary school Mathematics for the analysis of module development needs in the Doctoral Degree (Educational Technology) study at Universiti Putra Malaysia (UPM).

Name of Expert Teacher:

Position:

Date/ Time:

Starting the interview

1. Thank you, teacher, for taking the time for this interview session. The purpose of this interview is to gather information and perspectives from teachers on issues that arise in secondary school Mathematics education. I request permission from the teacher to record this interview for my research only. The teacher's information will be kept confidential and used solely for this study.

Initial Questions

1. To begin with, you were chosen for this interview because I recognized your expertise as a Mathematics teacher in this school. How long have you been teaching mathematics?
2. For which form have you taught Mathematics?
3. To what extent do you currently integrate technology, including smartphones or other devices, into your teaching practices?

Interview Questions

1. What do you think about the recent TIMSS PISA findings?
2. In your opinion, what changes need to be made in teaching and learning in the classroom to improve achievement in Mathematics?
3. What topics need to be given attention so that the level of Mathematics achievement of Form 2 students can be improved?

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4. Is smartphone integration suitable for improving the effectiveness of the teaching and learning process for this topic?
5. If a teaching module for this topic is developed, what will be emphasized in the module?
6. Are you confident that the use of technology can help students understand the topic and can make homework or exercises on the subject easier to complete?

Ending the Interview

Thank you, teacher, for this interview session. The information you shared is significant in my research and is subject to confidentiality ethics that must be maintained.