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Research Article

Validity and Reliability of the Motivation Questionnaire in Learning Programming using the Augmented Reality Module: A Pilot Study

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Abstract

Malaysian secondary school students face significant motivational challenges in learning programming hinder intrinsic motivation, including low self-efficacy, limited immediate feedback, and passive learning environments. To address these issues, Augmented Reality (AR) has been introduced as a potential instrument to measure student motivation in programming education. However, there is a lack of validated motivation instruments that specifically include AR to assess motivation in programming education for Malaysian secondary students. Therefore, this study developed a motivation questionnaire adapted from the Instructional Materials Motivation Survey (IMMS), namely the Motivation Questionnaire for Programming Learning with Augmented Reality (MQAR). MQAR was validated by seven experts, consisting of content experts and technological experts. Then, a pilot study was conducted at one Malaysian secondary school among 30 Form 4 students selected through purposive sampling to evaluate the reliability of MQAR. Next, the gathered validated data were analyzed using experts' percent agreement, and reliability was evaluated using Cohen's D. The findings showed that MQAR had high content validity at 99.26% and technological validity at 99.45%. This study also found that MQAR is a reliable instrument to measure students' motivation when using programming learning with AR modules, with Cronbach's alpha values indicating good internal consistency across the four motivation constructs: attention ($\alpha = 0.85$), relevance ($\alpha = 0.78$), confidence ($\alpha = 0.73$), and satisfaction ($\alpha = 0.82$). The overall reliability of the instrument was $\alpha = 0.80$. This confirms that the MQAR is a valid, reliable, and strong instrument for measuring student motivation in learning programming education with the AR module. This study contributed a validated, interactive motivation questionnaire (MQAR) to evaluate students' motivation in learning programming. It supports the Malaysian Digital Education Policy (DPDM) by promoting AR integration to enhance engagement and digital skills.

Keywords: validity, reliability, augmented reality, programming, student motivation

INTRODUCTION

The incorporation of computer science into Malaysia's secondary school curriculum (KPM, 2016) highlights the increasing role of programming in fostering learners' computational thinking skills (Jacob et al., 2024; Zainil et al., 2022). However, students encounter great difficulty in mastering programming due to the abstract concepts such as variables and loops (Cheah, 2020), and the rigid nature of teaching frameworks (Fojcik et al., 2022). This challenge leads to low self-efficacy (Gunbatar & Karalar, 2018), delayed feedback (Garcia et al., 2020), and passive learning environments (Suhag et al., 2016) that reduce intrinsic motivation.

Students' motivation is important for overcoming challenges. It encourages persistence (Tsai & Lai, 2022), engagement with diverse challenges (Medeiros et al., 2019), and the use of computational thinking (Puganesri & Puteh, 2019). Additionally, Yong and Tiong (2022) found that students' lack of programming background often resulted in low motivation among students and challenging to meet the psychological needs for autonomy and competence. To address these issues, previous studies have explored new teaching methods and the use of AR in programming education. Cevahir et al. (2022) emphasised that AR-based animation improved students' programming performance, motivation, and attitudes compared to the traditional learning approach. Tsai and Lai (2022) also stated that AR-based puzzle card instruction improved students' programming results, increased motivation, and reduced cognitive load. Zainal Abidin and Abdullah Zawawi (2020) observed that the OOP-AR application increased student interest, understanding, and satisfaction in learning object-oriented programming. Kao and Ruan (2022) found that interactive AR embedded in puzzle cards improves students' achievement, motivation in programming, and reduces cognitive load. Additionally, Salini (2025) stated that the AR-based module significantly improved students' programming achievement and motivation. Unlike traditional and low-interaction methods, technology-embedded learning offers better engagement (Sudin et al., 2022; Azman et al., 2024).

There are several instruments designed to evaluate students' motivation in programming. One of these instruments is the Instructional Materials Motivation Survey (IMMS) developed by Keller (2010). Then IMMS was changed into the Learning Motivation towards Linear Programming (LMLP) Questionnaire. The instrument demonstrated high reliability and validity among diploma students enrolled in mechanical engineering programming courses, as reported by Mohamad and Siew (2022). Next, a questionnaire, namely the Motivated Strategies for Learning Questionnaire, was designed to evaluate motivational factors among programming courses students (Silva et al., 2023). Similarly, the Academic Motivation Scale assesses intrinsic and extrinsic motivation and amotivation (Ankora et al., 2024). Latif et al. (2024) confirmed a University Student Learning Motivation Instrument. This instrument measures intrinsic motivation, amotivation, and extrinsic motivations linked to career and social factors. It offers a useful tool for assessing motivation in higher education programming courses. Gamification studies in programming education have used motivation measurement tools to evaluate the impact of game elements on student motivation, demonstrating improvements in engagement and reduction in failure rates (Figueiredo & Garcia-Penalvo, 2020). Lastly, the use of educational resources such as self-assessment questionnaires and automated grading embedded in learning management systems such as Moodle, alongside screencasts, has gained attention as a motivating factor in programming courses with students' motivation and learning dynamics (Saad et al., 2022).

Although previous studies have measured student motivation in learning programming, there is a lack of studies that have evaluated the expert validity and reliability of motivation questionnaires specifically within the context of AR-based programming modules. This study aims to address this gap by examining the validity and reliability of a motivation questionnaire made for programming learning using AR modules for Malaysian secondary school students. Specifically, this study aims to:

1) To develop the Motivation Questionnaire for Programming Learning with Augmented Reality (MQAR), adapted from the Instructional Materials Motivation Survey.
2) To evaluate the content and technological validity of MQAR through expert review.
3) To assess the reliability of MQAR using a pilot study among Malaysian secondary school students.

To achieve these objectives, the study addresses the following questions:

1) What is the validity of the motivation questionnaire for the programming learning module based on content and technology experts' perspectives?'
2) What is the reliability of the Motivation Questionnaire for Programming Learning with Augmented Reality module?

By addressing these questions, this study contributes a methodological approach for validating the motivation questionnaire. In addition, this study offered insights into effective methods to examine the reliability of instruments such as questionnaires. Most significantly, the novelty of this study is in validating and measuring the reliability of MQAR, an AR motivation questionnaire. Meanwhile, the existing questionnaire focused solely on measuring motivation in general.

LITERATURE REVIEW

Programming Education

In today's knowledge-driven world, the demand for science, technology, and skilled professionals is steadily growing (Pease et al., 2020). Integrating science, technology, engineering, and mathematics (STEM) in schools has been a major attempt to address this need (Gul & Ayik, 2024; Samuri et al., 2021). STEM education encompasses science, technology, engineering, and mathematics, and connects these disciplines with real-world problem-solving (Moore et al., 2014). This interdisciplinary approach not only cultivates higher-order thinking, critical reasoning, and problem-solving skills in both teachers and students (Bybee, 2013) but is also essential for student success in the era of Industrial Revolution 4.0 (Abdurrahman, 2019; Mohamad Kasim et al., 2023).

Therefore, the Ministry of Education (MOE) in Malaysia has integrated computer science into the high school curriculum as part of the Malaysia Education Blueprint 2013–2025 (KPM, 2016; Rahman et al., 2021). The MOE aims to enhance student engagement through new learning methods while improving curriculum quality (Rahman et al., 2021). Within the computer science (CS) curriculum, students are introduced to the basic principles of programming, how digital systems function, and how to apply this knowledge through programming (Almdahem, 2024).

Learning programming requires students to understand language rules and the semantics of various constructs (Vinnervik, 2023). Feurzeig et al. (1970) introduced programming as a way for students to understand mathematical concepts like variables, functions, and problem-solving techniques. The acquisition of 21st-century skills is crucial for addressing the complex challenges of modern society (Kishore et al., 2024; Ghafar et al., 2023). However, students report low self-efficacy and confidence and suffer from lagging motivation, all contributing to the struggle in learning programming during their course. Alongside motivational issues, barriers of cognition impose an equally important role. Students are unable to grasp fundamental concepts like loops, variables, and algorithms (Cheah, 2020), claiming to be overloaded with abstract concepts. Cheng and Tsai (2020) further reiterate the problem by stating that while trying to understand numerous complicated concepts at the same time, an individual's cognitive load tends to increase. It can be further hindered due to a lack of foundational skills, wherein misconceptions are bound to occur at some point (Qian & Lehman, 2017). Although these barriers continue to persist, new technologies such as AR offer solutions that can enhance learning. The next subtopic describes explicit literature on students' motivation in programming and how AR has been applied in past literature to mitigate these barriers and enhance programming education.

Students' Motivation in Learning Programming

Motivation has always been identified as a key element in the teaching and learning of programming. Students in particular face learning difficulties in programming because it is abstract and requires high-level algorithmic thinking (Cheah, 2020). In addition, learning programming requires students to efficiently understand language rules and semantics of various constructs, which poses a cognitive challenge (Vinnervik, 2023). Moreover, a lack of self-efficacy with students' skills in programming hinders their confidence and willpower to work hard (Gunbatar & Karalar, 2018). Yong and Tiong (2022) noted that intrinsically motivated students are more self-driven and therefore use more time and energy to learn programming as compared to those motivated by rewards. This self-motivation greatly supports students in learning to program because they need to develop and apply problem-solving skills to multifaceted cognitive challenges.

Augmented Reality (AR) as a Motivational Tool in Programming Education

Student motivation is a key factor that affects engagement and persistence in learning, especially in programming. Current technologies, such as AR, provide new ways to increase student motivation through interactive and immersive activities (Gopalan et al., 2016). AR technology has proven to motivate active learning and positively reinforce intrinsic learning motivation by digitally augmenting elements (Raposo et al., 2020). The interactivity and immersive experience of AR help students understand programming concepts like loops, variables, and algorithms better (Kesim & Ozarslan, 2012; Rahmadani & Sunarmi, 2023). Recent studies show that AR effectively increases student motivation in programming settings. Yildiz (2021) found that immersive AR boosts enjoyment and engagement while learning programming. These results align with Pujiastuti and Haryadi (2023), who emphasised that using AR tools during programming lessons significantly raised students' motivation. Similarly, Cevahir et al. (2022) highlighted that animation-based AR applications encouraged more enthusiasm among coding students. Furthermore, Bursali and Yilmaz (2019) noted that AR-enhanced learning environments improved motivation, lowered anxiety related to programming, and improved learning experience.

Supporting this, Yang et al. (2023) found that students who used AR-driven robotics for programming reported more enjoyment and interest. Chuan et al. (2023) designed an AR Bot that provided 3D feedback and noted improved motivational levels among students, although there were no changes to academic performance. Ivarson et al. (2024) also found that combining AR with gamification improved motivation in a web development course. Aydin and Cakiroglu (2024) designed an AR-based programming editor using real-world metaphors to stimulate learner interest and motivation through dynamic code visualizations.

The literature demonstrates that AR has significant potential to boost student motivation in programming education. However, while many studies claim improvements in motivation, a notable limitation is that few rigorously validate their motivation measurement tools. Most rely on self-developed questionnaires, lacking detailed reporting on content validity through expert review or statistical reliability measures, such as Cohen's Kappa. This raises concerns about the accuracy and consistency of the motivational data collected. Therefore, this study aims to conduct a pilot study on the validity and reliability of a motivation questionnaire adapted from the Instructional Materials Motivation Survey (Keller, 2010), among 30 Form 4 students learning programming using AR.

Measuring Motivation

A questionnaire developed by John M. Keller provides a framework for understanding and measuring motivation in educational contexts. The questionnaire addresses four constructs consist of Attention (A), Relevance (R), Confidence (C), and Satisfaction (S) (Keller, 2010). As Cardenas and Ibarra (2022) noted, this questionnaire can be implemented in various learning settings.

In advancing the ARCS model of motivation, Keller (2010) designed the Course Interest Survey (CIS) for instructor-guided environments and the Instructional Materials Motivation Survey (IMMS) for contexts of autonomous study. Attention addresses the extent to which learners are drawn to the subject matter. Relevance evaluates how closely the language and situational context resonate with the learners' prior knowledge and goals. Confidence gauges the learners' conviction that they can achieve a successful outcome. Satisfaction reflects the perceived rewards or benefits that the learners derive from the educational experience.

Numerous investigations have employed the Instructional Materials Motivation Survey (IMMS) to quantify student motivation across various technology-mediated pedagogical interventions. Cook et al. (2009) and Loorbach et al. (2015) used IMMS in remote and computer-aided education frameworks related to programming for measuring the motivational impact of instructional design and in web-based education. IMMS is a robust, widely adopted tool to quantitatively measure the motivational impact of technology-mediated instructional design. However, Loorbach et al. (2015) highlighted current limitations include a focus on short-term, surface-level motivational changes, limited adaptation to cultural contexts, and validation and scoring complexities. Therefore, there is a need to develop a validated instrument to measure students' motivation.

Validity and Reliability of the Instrument

In research, validity and reliability are very important in validating measurement tools as effectiveness as evaluators and adequacy measures of instruments (Mohajan, 2017; Sundram & Romli, 2023). An expert's inspection determines validity based on how well an instrument attempts to measure a specific construct. Reliability involves obtaining estimates of the consistency of a test, often with regard to a pilot study. Reliability is overly undermined because the presumption of reliability is the sole first step in establishing, beyond a reasonable doubt, the scientific credence and practicability of a test. Equally, as Mohajan (2017) noted, validity and reliability focus on measurement error, which means that in all instruments that are valid and reliable, biases are less, and hence the trustworthiness of scores is high. For the motivation questionnaire to yield valid and reliable results, this study intends to conduct a pilot study to validate the motivation questionnaire for the programming learning module with AR.

RESEARCH METHODOLOGY

This study conducted a pilot test to evaluate students' motivation in learning programming by integrating AR using the Motivation Questionnaire for Programming Learning with Augmented Reality (MQAR) questionnaire. This study contained two sets of samples, including four technological experts and three content experts, and 30 secondary school students. The samples were selected using purposive sampling.

Set I: Expert Panel for Instrument Validation

The first sample includes a panel of seven experts, consisting of four technological experts and three content experts were selected to validate the MQAR motivation questionnaire. The number of experts is consistent with generally acknowledged methodological guidelines for content verification and validation. According to Lynn (1986), a panel of at least five experts is necessary to achieve a reliable consensus. This supports the appropriateness of a seven-expert panel in this context. This panel size ensures sufficient expertise and diverse perspectives while maintaining efficient coordination and high response rates during the validation process.

Table 1 shows the demographic information of the technological experts, including experience, validation content, AR knowledge, and expertise field. The group of four technology experts comprised an equal gender distribution, with two male and two female participants. Next, three computer science teachers participated in the validation of the MQAR motivation questionnaire, as shown in Table 2. The panels were selected based on specific criteria as shown in Table 3. School teachers were (i) having more than five (5) years of teaching experience, (ii) having expertise in computer science, (iii) having basic knowledge of mobile applications and AR, and (iv) having experience in fabricating and grading test papers. The AR experts were expected to (i) possess basic education knowledge, (ii) have seven (7) years of experience in developing mobile applications, and (iii) demonstrate expertise in marker-based AR.

Table 1: Demographics of respondents for validation (AR Experts)

Expert	Experiences in Teaching	AR Knowledge	Expertise Field
Expert 1	4 years	Expertise	1) Educational Technology and Media 2) Mobile AR, Multimedia
Expert 2	5 years	Expertise	1) AR 2) Human Computer Interaction
Expert 3	15 years	Expertise	1) Edutainment (e-learning, AR, Interactive Teaching/learning Applications) 2) Computer Animation & Multimedia
Expert 4	10 years	Expertise	1) Computer-Based Learning System 2) Education Technology and Media AR in Education

Table 2: Demographics of respondents for validation (Teachers)

Teacher	Experiences in Teaching	Education Expertise	Programming Expertise
Teacher 1	14 Years	Excellent	Excellent: HTML, Java, JavaScript, C#, C, Python
Teacher 2	10 Years	Excellent	Good: Java, C
Teacher 3	5 Years	Excellent	Excellent: HTML, Java, JavaScript, C#, C, Python, Csharp

Table 3: Expert Criteria for Instrument Validity

Experts	Criteria	Number of Experts
Technological Expert	1) University Lecturer with Multimedia Background 2) Expertise in AR 3) Expertise in Computer Science	4 Experts
Content Expert	1) Teaching computer science for at least 7 years 2) Basic mobile application knowledge	3 Experts
Overall		7 Experts

Set II: Secondary School Students

The second sample of this study involved 30 Form 4 Computer Science students from one Malaysian school selected through purposive sampling. Julious (2005) recommends a minimum of 12 participants per group for pilot testing. Additionally, Hertzog (2008) suggests 10 to 40 participants as appropriate for pilot studies. A pilot study is a small-scale version of the main study that helps improve the quality and feasibility of the full research. It allows researchers to test instruments and procedures and identify potential issues before conducting the actual study. Furthermore, pilot studies carried out in a single school setting aid in evaluating the viability of research procedures and design in a controlled setting. This aims to minimize variability introduced by multiple sites and allow clearer identification of potential issues (Teijlingen & Hundley, 2002). Therefore, the 30 students should be appropriate to conduct this pilot study.

Significantly, the samples of this study were selected through purposive sampling based on the five criteria: (i) enrolled in Form 4 Computer Science, (ii) school that offers Computer Science as an elective subject, (iii) age range between 16 and 17 years, (iv) experience in using mobile applications, and (v) fundamental knowledge of programming subjects.

Research Procedure

The pilot study was conducted over a period of five weeks. Initially, the MQAR was validated by seven experts using an evaluation rubric. Based on the experts' feedback, necessary improvements were made to enhance the clarity and relevance of the questionnaire items. Following the validation process, a programming module named SmartAR Module was implemented as a pilot study to teach the control structure topic from the Form 4 programming subject. At the end of the pilot study, the MQAR was distributed to measure students' motivation in learning programming, as shown in Figure 1.

(a) (b)

Figure 1: (a) Participants use the SmartAR application to scan the module and learn, (b) participants answering the MQAR motivation questionnaire

Following the data collection, in order to measure the reliability of MQAR, a descriptive analysis was conducted using Cronbach's alpha in Statistical Package for the Social Sciences (SPSS) version 29.0.0. The intention is to measure the internal consistency of the questionnaire.

Research Instruments

The instrument of this study is a questionnaire, namely the Motivation Questionnaire for Programming Learning with Augmented Reality (MQAR). This questionnaire consisted of two sections. Section A focused on student demographics, with items developed by the researchers. Next, section B comprised motivation-related items adapted from Keller's (2010) Instructional Materials Motivation Survey (IMMS), covering four constructs: Attention, Relevance, Confidence, and Satisfaction. This section included a total of 30 items (refer to Table 5). A five-point Likert scale, as shown in Table 4, was used to allow respondents to indicate their level of agreement with each item.

Table 4: Range of interval scale used

Scores	**1**	**2**	**3**	**4**	**5**
Category	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

To interpret the motivation levels, a scale similar to that used by Zainuddin et al. (2020) was adopted. The scores were categorized as: very low (1.00-1.80), low (1.81-2.60), moderate (2.61-3.40), high (3.41-4.20), and very high (4.21-5.00).

Table 5: Section of students' motivation questionnaire

Section	**Description**	**Example Item**	**Source**	**Total Item**
A	Demographic		Self-developed	3
B	Motivation		Adopted from Keller, 2010)	27
	Attention	When I first looked at the programming module, I had the impression that studying from it would be easy for me.		
	Relevance	It is clear to me content of the programming module is related to things I already know.		
	Confidence	As I used the programming module, I was confident that I could learn the content.		
	Satisfaction	It was a pleasure to work on such a well-designed programming module		
		Overall		30

RESULTS

Validity of the MQAR

Table 6 presents the content validity results of the Motivation Questionnaire for Programming Learning with Augmented Reality (MQAR) as evaluated by three school Computer Science teachers. The content validation process employed a 10-point rating scale with qualitative interpretation categories (1–2: Need Improvement, 3–4: Average, 5–6: Fairly Good, 7–8: Good, 9–10: Excellent). The interpretation is consistent with common practices in educational instrument development (Sundram & Romli, 2023; Che Lah et al., 2021).

All experts rated the MQAR items as highly relevant and well-aligned with the DKSP Malaysia Form 4 Computer Science curriculum. The mean scores ranged from 9.33 to 10.00 across criteria. Specifically, items were rated excellent for curriculum alignment, organization, clarity, and relevance to students' everyday learning experiences. Two experts (Experts 1 and 2) rated MQAR's adequacy in enhancing students' logical and technical skills as excellent, while one (Expert 3) rated it as good. Similarly, the items' connection to real-world applications received excellent ratings from two experts and a good rating from one.

Table 6: Content validation by school teachers' perspectives

No.	Item/Criterion	Expert 1	Expert 2	Expert 3	Mean Score (/10)	% Score	Interpretation
1	Well-aligned with the existing school curriculum	10	10	10	10.00	100	Excellent
2	Well-organized and easy to understand	10	10	10	10.00	100	Excellent
3	Practical and relevant to students' everyday learning experiences	10	10	10	10.00	100	Excellent
4	Effectively provides logical skills that enhance students' technical abilities	10	8	10	9.33	93.33	Excellent
5	Engages students and connects well to real-world applications	8	10	10	9.33	93.33	Excellent
6	Relative to the DKSP Malaysia Form 4 curriculum	10	10	10	10.00	100	Excellent
	Overall Mean				9.78	97.78	Excellent

Indicator Note: 1–2: Need Improvement, 3–4: Average, 5–6: Fairly Good, 7–8: Good, 9–10: Excellent.

The overall mean score for content validity was 9.78 out of 10 (97.78%), indicating strong expert agreement on the questionnaire's content quality. This score demonstrates the extent to which these materials improve the teaching of programming by increasing interactivity, structure, and relevance to the students, thereby actively engaging learners. In addition, Table 7 presents the technological validity results of the Motivation Questionnaire for Programming Learning with Augmented Reality (MQAR) as evaluated by four lecturers with expertise in AR and multimedia.

All four experts equally agreed that the questionnaire items reflect technological features and scores (10/10) to this criterion. That indicates realistic, contextually relevant, and well-suited for integration into secondary school programming education. Similarly, the experts fully concurred that each item effectively captures the technological potential of AR in enhancing teaching and learning outcomes. All experts provided scores (10/10) for clarity and contextual appropriateness. It confirms that the wording is accurate, clear, and appropriate for a learning environment that supports AR programming. The questionnaire's overall technological design and suitability for assessing student motivation within AR-based educational contexts were rated as excellent by all experts. All experts gave the "Confidence" items, which assess how AR-based learning improves students' perceived comprehension and application of programming concepts, high ratings. Three experts gave perfect scores (10/10), while one gave a slightly lower score of 8/10. The experts generally agreed that most items in the questionnaire worked well, though they offered a few suggestions for minor improvements. Finally, the items designed to evaluate the relevance of the AR content to students' real-life experiences and pre-existing knowledge were rated as excellent by every expert, without a single dissenting opinion.

Table 7: Technological validation from lecturers' perspectives

No.	Item/Criterion	Expert 1	Expert 2	Expert 3	Expert 4	Mean Score (/10)	% Score	Interpre-tation
1	The technological features reflected in the questionnaire items are realistic, contextually relevant, and well-suited for integration into secondary school programming education.	10	10	10	10	10.00	100	Excellent
2	Each item in the questionnaire effectively captures the technological potential of AR in enhancing teaching and learning outcomes	10	10	10	10	10.00	100	Excellent
3	The language used in the items is clear, accurate, and contextually appropriate for an AR-supported programming learning environment.	10	10	10	10	10.00	100	Excellent
4	The questionnaire is technologically well-designed and suitable for assessing student motivation within an AR-based educational context.	10	10	10	10	10.00	100	Excellent
5	The 'Confidence' items effectively evaluate how AR-based learning enhances students' perceived ability to understand and apply programming concepts.	8	10	10	10	9.50	95.00	Excellent
6	The 'Relevance' items accurately assess the extent to which the AR content aligns with students' real-life experiences and prior knowledge in programming.	10	10	10	10	10.00	100	Excellent
	Overall Mean					9.81	98.13	Excellent

Indicator Note: 1–2: Need Improvement, 3–4: Average, 5–6: Fairly Good, 7–8: Good, 9–10: Excellent.

Overall, the MQAR received a mean technological validity score of 9.81 out of 10 (98.13%). This score shows strong expert agreement on the instrument's technology, clarity, and suitability for AR-based programming education. In addition, Table 8 shows the expert qualitative comments stated in the validation form. The qualitative feedback shows the validity and robustness of MQAR in measuring students' motivation in the programming subject. Content experts stated the MQAR questionnaire is comprehensive and aligned with the programming curriculum. Meanwhile, technology experts noted that MQAR is practical and easy to integrate into AR learning environments. The experts also highlighted the questionnaire's potential in determining lessons' interactive, intellectually stimulating aspects. Overall, this positive feedback shows that the MQAR is a credible and useful instrument for future studies involving AR technology.

Table 8: Comments given by all the experts

Experts	Comment
Content Expert I	It can significantly improve students' programming motivation. The attention items effectively capture AR's ability to make abstract coding concepts more engaging.
Content Expert II	Can enhance programming motivation through well-structured relevance items. The real-world problem examples directly connect coding to student interests.
Content Expert III	It can boost motivation in programming education. The confidence-building items successfully address beginners' anxiety in coding tasks.
Technological Expert I	Can effectively track programming motivation through AR. The attention items perfectly capture how AR visualizations engage students with complex code structures.
Technological Expert II	Can measure programming motivation accurately via AR interfaces. The real-time feedback items demonstrate a strong capacity to boost coding confidence through interactive debugging.
Technological Expert III	All items scored Excellent in technological appropriateness. The satisfaction dimension could benefit from distinguishing between interface usability and learning enjoyment.
Technological Expert IV	Remarkably strong tool that connects AR technology with teaching goals. The high scores in relevance items show how programming concepts relate to real-world applications.

Reliability of the MQAR

This section shows the sample demographic of the pilot study and the findings of the reliability of MQAR. In this pilot study, 30 computer science students participated by answering motivation questionnaires related to the programming subject. Table 9 shows their demographic information, including gender, enrolment in computer science courses, and their previous knowledge of mobile technology and AR. From the study conducted among 30 computer science students, it was observed that female students constituted 90% of the population while male students accounted for 10%. It is noteworthy that all respondents (100%) were enrolled in the Form 4 computer science subjects.

Table 9: Demographics of respondents for the motivation questionnaire

Demographic	Category	Frequency (f)	Percentage (%)
Gender	Male	3	10
	Female	27	90
Register computer science subject	Yes	30	100
	No	0	0
Prior mobile learning knowledge	Yes	21	70
	Neutral	8	26.7
	No	1	3.3
Augmented Reality Knowledge	Yes	21	70
	No	9	30

Concerning prior knowledge on mobile learning experiences, 70% of students had mobile learning experience, 26.7% were neutral, and 3.3% had no prior experience. In regard to AR knowledge, 70% of students had some form of understanding regarding AR, though 30% of students did not understand the technology at all. The data of this particular participant’s demographic moves beyond the age of the participants, which helps understand the motivation questionnaire better in terms of willingness and the prior knowledge they possessed.

This pilot study evaluated the motivation of 30 secondary students using the AR module. As outlined in the results section, the reliability of the motivational instrument was assessed using Cronbach's alpha in Statistical Package for the Social Sciences (SPSS). Table 10 illustrates the significant Cronbach's Alpha indicator used by Tavakol and Dennick (2011) as follows in this study.

Table 10: Expert criteria for SmartAR module validity

Cronbach's Alpha Value	Indicator of Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Unacceptable
$0.5 > \alpha$	Highly Unacceptable

The reliability analysis of MQAR indicated that all four constructs, Attention, Relevance, Confidence, and Satisfaction, had strong internal consistency as presented in Table 11.

Table 11: Cronbach's alpha values for the MQAR

Motivation	Items	Cronbach's Alpha (α)	Internal Consistency
Attention	Q4: The items in the motivation questionnaire are eye-catching.	0.715	Acceptable
	Q5: Something was interesting in the items in the motivation questionnaire that got my attention.	0.698	Acceptable
	Q6: The quality of the content in the items in the motivation questionnaire notes helped to hold my attention.	0.666	Questionable
	Q7: The way that information is presented on the items in the motivation questionnaire helped keep my attention.	0.661	Questionable
	Q8: I learned some things that were surprising or unexpected from the items in the motivation questionnaire.	0.630	Questionable
	Q9: It was a pleasure to work on such a well-designed item in the motivation questionnaire	0.667	Questionable
	Q10: The items in the motivation questionnaire have things that stimulated my curiosity.	0.665	Questionable
	Q11: When using the items in the motivation questionnaire, there is so much information on the screen that it is irritating.	0.665	Questionable
	Overall	**0.85**	**Good**
Relevance	Q12: The content of the items in the motivation questionnaire will be useful to me.	0.740	Acceptable
	Q13: I could relate the content of the items in the motivation questionnaire to things I have seen, done, or thought about in my own life.	0.732	Acceptable
	Q14: The items in the motivation questionnaire were not relevant to my needs because I already knew most of them.	0.762	Acceptable
	Q15: The content of the items in the motivation questionnaire is relevant to my interests.	0.745	Acceptable
	Q16: There were stories, pictures, or examples that showed me how the information in the items in the motivation questionnaire could be important to some people.	0.710	Acceptable

	Overall	**0.78**	**Acceptable**
Confidence	Q17: I could not really understand quite a bit of the material in the items in the motivation questionnaire.	0.705	Acceptable
	Q18: After working with the items in the motivation questionnaire for a while, I was confident that I would be able to answer the programming test.	0.680	Questionable
	Q19: As I used the items in the motivation questionnaire, I was confident that I could learn the content.	0.666	Questionable
	Q20: After downloading the items in the motivation questionnaire, I felt confident that I knew what I was supposed to learn from the mobile application.	0.690	Acceptable
	Q21: The good organisation of the content on the items in the motivation questionnaire helped me be confident that I would learn this material.	0.695	Acceptable
	Q22: I could not really understand quite a bit of the material in the items in the motivation questionnaire.	0.690	Acceptable
	Overall	**0.73**	**Acceptable**
Satisfaction	Q23: When I first looked at the items in the motivation questionnaire, I had the impression that studying from it would be easy for me.	0.803	Good
	Q24: After working with the items in the motivation questionnaire for a while, I was confident that I would be able to answer the programming test.	0.792	Acceptable
	Q25: The amount of repetition in the items in the motivation questionnaire caused me to get bored sometimes.	0.811	Good
	Q26: I really enjoyed using the items in the motivation questionnaire.	0.779	Acceptable
	Q27: I enjoyed studying from the items in the motivation questionnaire so much that I would like to know more about this topic.	0.773	Acceptable
	Q28: Successfully learning from the items in the motivation questionnaire is important to me.	0.785	Acceptable
	Q29: When I first looked at the items in the motivation questionnaire, I had the impression that studying from it would be easy for me.	0.781	Acceptable
	Q30: After working with the items in the motivation questionnaire for a while, I was confident that I would be able to answer the programming test.	0.773	Acceptable
	Overall	**0.82**	**Good**
	Overall Items	**0.80**	**Good**

The internal consistency of the MQAR was assessed using Cronbach's alpha across the four constructs such as Attention, Relevance, Confidence, and Satisfaction. In the Attention construct, individual items showed Cronbach's alpha values ranging from 0.630 to 0.715. Specifically, Q4 (0.715), Q5 (0.698), Q6 (0.666), Q7 (0.661), Q8 (0.630), Q9 (0.667), Q10 (0.665), and Q11 (0.665) all demonstrated acceptable levels of internal reliability. The overall Cronbach's alpha for this construct was 0.85, indicating a good level of internal consistency, suggesting that the items effectively measured learners' attention toward the content.

For the Relevance construct, item values ranged from 0.710 to 0.762. Q12 (0.740), Q13 (0.732), Q14 (0.762), Q15 (0.745), and Q16 (0.710) all indicated good consistency, with the overall Cronbach's alpha value of 0.78. This shows that the elements within this construct exceeded the threshold of capturing the relevance of the content to the learner's needs and interests.

In the Confidence construct, individual item Cronbach's alpha values ranged from 0.666 to 0.705. Items Q17 (0.705), Q18 (0.680), Q19 (0.666), Q20 (0.690), Q21 (0.695), and Q22 (0.690) showed acceptable to good levels of consistency. The overall Cronbach's alpha for this construct was 0.73, which supports the internal reliability of the items. This helps to evaluate students' confidence in their ability to learn and complete programming tasks using the Motivation Questionnaire for Programming Learning with Augmented Reality (MQAR).

The Satisfaction construct showed strong internal consistency in individual items' measurement, ranging from 0.773 to 0.811. Q23 (0.803), Q24 (0.792), Q25 (0.811), Q26 (0.779), Q27 (0.773), Q28 (0.785), Q29 (0.781), and Q30 (0.773) all indicated good to very good reliability. The overall Cronbach's alpha value for this construct was 0.82, demonstrating that the items effectively captured students' satisfaction with the learning experience.

Overall, the total Cronbach's alpha value for all items across the four constructs was 0.80 and indicates good internal consistency. This value suggests that the instrument was a reliable tool for assessing students' motivational responses based on the four motivation constructs after engaging with the MQAR.

DISCUSSION

Discussion of the Validity of the MQAR

In this study, the MQAR was validated by both content and technology experts. These validation steps were taken to ensure the questionnaire meets practical classroom needs and relevant education theories (Mohajan, 2017; Sundram & Romli, 2023). MQAR was also validated by content experts, consisting of three computer science teachers, to ensure items align with are Malaysian Form 4 Computer Science curriculum (KPM, 2016). This alignment supports the questionnaire's ability to address key challenges in programming education effectively entails promoting abstract thinking and improving algorithmic understanding (Cheah, 2020). To effectively address challenges in programming education and measure students' motivation, previous studies have applied validated motivation instruments. These include the Instructional Materials Motivation Survey (IMMS) (Cook et al., 2009; Loorbach et al., 2015), the Motivated Strategies for Learning Questionnaire (MSLQ) (Silva et al., 2023), the Academic Motivation Scale (AMS) (Ankora et al., 2024), and the University Student Learning Motivation Instrument (Latif et al., 2024).

However, the lack of validation in the motivation instrument for Malaysian Form 4 programming students significantly limits its use in different contexts. Previous studies showed that existing instruments increased students' motivation in learning programming using AR (Yildiz, 2021; Pujiastuti & Haryadi, 2023). However, most of these studies relied on self-developed tools that were not tested for accuracy. Most evidence comes from post-secondary settings or general motivation assessments. This limits their direct application for secondary programming learners in Malaysia. This shows the need for a specific tool like MQAR that reflects both curriculum content and the unique cognitive and motivational needs of secondary programming education.

MQAR fills a critical gap through systematic validation and curriculum alignment. The content and technology resulted in reliable (CVI > 0.90, $\alpha = 0.89$) and context-appropriate measurement. These results align with previous STEM motivation studies, which highlight the critical role of expert consensus in maintaining item quality and theoretical coherence (Zhang & Yu, 2022). In these studies, expert agreement also supported the quality of the items. Zhang and Yu (2022) emphasized the need to improve motivation tools for real-world use.

Despite these positive indicators, items that assess logical reasoning and real-world application in MQAR received lower expert ratings. This highlights a challenging issue in measuring motivation in programming education, where capturing abstract reasoning and practical application is tough. Wen et al. (2023) and Tavares et al. (2018) have also noted that the difficulty of evaluating motivation requires higher-order thinking tasks and contextual learning in programming. Future improvements to MQAR should include qualitative methods, such as interviews and think-aloud protocols, to gain a better understanding of student interpretations of these complex items and improve their sensitivity.

The MQAR benefits from a combined content and technological validation approach. This allows the instrument to capture motivational elements related to spatial understanding in AR learning environments more effectively (Cevahir et al., 2022). However, since MQAR was designed based on the Malaysian curriculum, its usefulness may be limited in other educational settings. To improve its wider use, future studies should focus on adjusting and revalidating the tool in different scenarios and subject areas. Additionally, the technological experts stated that technological items in MQAR contain positive feedback and reflect AR’s pedagogical strengths in programming education. Employing this multidimensional validation aligns with current best practices in educational technology instrument development. Confidence and Relevance are the two highly rated aspects that show the relevance of content in effective AR learning, supported by Cevahir et al. (2022) and Tsai and Lai (2022).

MQAR’s construct validity is grounded in Keller’s ARCS model: Attention, Relevance, Confidence, and Satisfaction. Validation of items in the attention aspect supports findings that AR's interactive and immersive features engage learners and keep their interest (Raposo et al., 2020). The relevance dimension emphasizes the need to connect AR content to students' prior knowledge and real-world contexts. This connection boosts intrinsic motivation (Vinnervik, 2023). Confidence items focus on learners' self-efficacy, which is essential for managing programming anxiety and encouraging persistence. This matches earlier studies (Cevahir et al., 2022; Tsai & Lai, 2022; Gunbatar & Karalar, 2018). Lastly, satisfaction items reflect the enjoyment and reward learners feel, which significantly increases motivation (Bursali & Yilmaz, 2019). Additionally, qualitative feedback from experts also supports MQAR’s practical use in capturing motivation aspects that affect cognitive development. Experts emphasized that AR helps make abstract coding concepts clear and lowers learner, reinforcing experiential learning advantages noted in the literature (Raposo et al., 2020). The focus on real-world relevance matches the need for practical programming education (Vinnervik, 2023). This further shows the instrument’s usefulness.

Overall, MQAR provides educators with a helpful questionnaire to identify and overcome motivational challenges in AR-based programming learning. This includes issues like low confidence or relevance, which enable focused instructional strategies (Cheng & Tsai, 2020). Future studies recommend using MQAR to evaluate the effectiveness of AR interventions in terms of motivational effects. Although AR has shown strong potential to boost motivation through immersive visualization and interactive problem-solving in programming education (Yildiz, 2021), there has been a lack of detailed, validated tools to measure these motivational effects. MQAR fills this gap with its systematic validation framework.

Discussion of the Reliability of Research Instruments

The reliability of the MQAR was measured using Cronbach's Alpha. In this pilot study, the MQAR questionnaire showed high reliability across all four motivational factors: attention, relevance, confidence, and satisfaction. All subscales had alpha values in acceptable (above 0.70) to good (above 0.80), according to the widely accepted criteria proposed by Tavakol and Dennick (2011).

As shown in Table 11, alpha values between 0.80 and 0.89 indicate good internal consistency, and 0.70 to 0.79 are acceptable. In this study, the overall Cronbach's alpha for MQAR was 0.80. These findings match the psychometric guidelines set by Nunnally and Bernstein (1994) and support previous studies that confirm the use of Cronbach's alpha in education. Since these are well-established instruments, exploratory factor analysis (EFA) was not needed in those studies. For similar reasons, EFA was not performed in this study because MQAR showed adequate reliability.

Additionally, previous studies in similar educational contexts support these findings. For example, Chang and Tseng (2011) found alpha values above 0.80 for motivation subscales in computer-assisted learning. Tsai and Lai (2022) reported alpha coefficients between 0.75 and 0.88 for motivation scales in tech-enhanced learning. Overall, these studies' findings support the MQAR's reliability as a solid instrument in measuring student motivation in AR-enhanced programming education.

Furthermore, the reliability of this study is supported by several theories, such as Keller's (2010) Instructional Materials Motivation Survey (IMMS) and Self-Determination Theory (Ryan & Deci, 2000). These frameworks suggest that learner motivation improves when educational instruments satisfy psychological needs for autonomy, competence, and connection. The items in the MQAR effectively reflect important aspects of motivation to ensure students engage through exploration, visual problem-solving, and social interaction (Chuan et al., 2023).

In an AR-based programming environment, where abstract logic and syntax can undermine learner confidence, measuring motivational factors like self-efficacy is essential (Gunbatar & Karalar, 2018; Cheah, 2020). The reliability of MQAR supports its use in these challenging situations. From a cognitive load perspective, AR reduces unnecessary load and improves relevant processing by visually supporting abstract programming content (Tsai & Lai, 2022). Thus, a reliable instrument like MQAR is vital for capturing the interplay of cognitive and motivational processes during learning.

Cronbach's alpha is often used to measure internal consistency reliability and shows the process of items in a scale relate to one another and measure the same concept (Field, 2013; Mohamad & Siew, 2022). However, relying solely on Cronbach's alpha to determine reliability and dimensionality can be misleading. It assumes that all items measure one basic factor and contribute equally, which may not hold for complex tools (Sijtsma, 2009; Tavakol & Dennick, 2011). Therefore, additional analyses like factor analysis are important. This will help assess the tool's dimensionality and verify if the scale effectively measures a unified concept (Nunnally & Bernstein, 1994; Field, 2013). Therefore, future studies should use confirmatory factor analysis (CFA) and test-retest reliability assessments to further establish MQAR's psychometric properties.

From an educational perspective, an instrument like MQAR is essential for use in various technology-based learning environments. Studies show that AR features, such as interactivity and gamification, significantly impact learner motivation over time (Ibanez et al., 2014; Bacca et al., 2014). For instance, Ibanez et al. (2014) found that gamified AR environments positively improve engagement among visual learners. The reliability and robustness of MQAR items can capture students' motivation and learning outcomes. This helps handle the challenges of creating educational tools tailored for specific local contexts while using broader frameworks, as discussed by Cheng and Tsai (2020). Overall, these findings suggest that MQAR could be helpful beyond the Malaysian curriculum. It needs future validation studies in various cultural and teaching settings to confirm its effectiveness and relevance.

In conclusion, the MQAR demonstrates strong internal consistency across its subscales and established motivational questionnaire. However, to improve its reliability, future validation efforts should include broader statistical tests, Exploratory Factor Analysis (EFA). Practically, the MQAR offers educators a dependable instrument to evaluate motivational strengths and weaknesses in AR-enhanced programming instruction. Future research can extend its application to various AR learning environments, facilitating the customization of instructional strategies and improving educational outcomes beyond the Malaysian context. This can help guide both instructional design and educational studies.

CONCLUSION

This pilot study found that the motivation instrument, namely Motivation Questionnaire for Programming Learning with Augmented Reality (MQAR), is a reliable and robust instrument to measure students' motivation in learning programming using AR. After validation by content and technology experts, the questionnaire achieved high content validity at 97.78% and technological validity at 98.13%. These results show excellent expert agreement on how well the questionnaire fits the Malaysian Form 4 Computer Science curriculum and its practical use in AR-supported learning environments. Experts highlighted the MQAR's ability to capture student attention, build confidence, and show the real-world relevance of programming.

Reliability analysis produced strong results, with Cronbach's alpha values for each area: Attention at 0.85, Relevance at 0.78, Confidence at 0.73, and Satisfaction at 0.82. The overall alpha was 0.80. These results confirm good internal consistency, matching established educational measurement standards and earlier studies in AR and technology-enhanced learning. The MQAR addresses a significant gap in previous motivation measures, including a lack of comprehensive validation and not being designed for secondary programming curricula in AR settings. This study provides evidence for the reliability and validity of the MQAR instrument. Therefore, it's easier for future studies focused on improving its psychometric evaluation and evaluating it in educational settings. Additionally, this study supports national digital education initiatives by backing the Malaysia Digital Education Policy. By offering a validated tool to evaluate AR interventions, the MQAR fits with efforts to integrate immersive technologies in classrooms, boost student motivation, and promote digital skills within programming education.

In summary, the MQAR stands out as a credible and practical tool for educators and researchers to assess and tackle motivational factors in AR-based programming education. This supports more effective instructional design and data-driven educational practices.

LIMITATIONS AND FUTURE SUGGESTIONS

This study has multiple limitations that have to be addressed. First, the sample was restricted to one school, which has a regional limitation. Lastly, the reliability evaluation of the MQAR was conducted solely through Cronbach's alpha. To address these issues, several suggestions are given for further studies. For future studies, verifying the MQAR tool in different schools with varying student demographics would greatly widen the range of the results, so this should be taken into consideration. Maybe further studies could be done where additional analyses, such as Exploratory Factor Analysis (EFA), are done to validate the MQAR instrument's reliability.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

Salini Krishna Pillai: Data Analysis, Data Collection, Original draft preparation, Visualisation, Investigation, Writing, and Editing. **Noor Hidayah Che Lah**: Supervision, Writing-Reviewing the manuscript. **Md Meem Hossain** Reviewing, Editing.

DECLARATION OF GENERATIVE AI

During the preparation of this work, the authors used ChatGPT to enhance the clarity of the writing. After using ChatGPT, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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