

PLS-SEM Approach: Validity and Reliability of a Questionnaire on Context, Input, Process and Acceptance of STEM Implementation in Malaysia

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Abstract

This study aims to test the validity and reliability of the context, input, process, and acceptance of STEM implementation questionnaires for secondary school teachers in Malaysia. Partial Least Squares Structural Equation Modelling (PLS-SEM) with SMARTPLS 3.2.3 software was used to do the analysis. The study involved 825 secondary school teachers using stratified random sampling. Based on composite reliability and Cronbach's alpha values, the Reflective Measurement Model showed that there was internal consistency reliability. Convergent validity was also achieved through outer loading analysis and average variance extracted (AVE). It also met the criteria for discriminant validity based on the Fornell-Larcker Criterion, Cross Loading, and the Heterotrait-Monotrait Ratio (HTMT). The findings of this study demonstrate that this questionnaire is valid and reliable for assessing STEM implementation among secondary school teachers in Malaysia. These results have a significant impact on educators and policymakers when they evaluate and enhance STEM programmes. Further studies are necessary to examine the predictive validity of this instrument in various educational contexts and to assess its capability to monitor changes in STEM implementation over time.

Keywords: Reliability, STEM education, questionnaire, validity

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1. Introduction

Through Malaysia's education targets, from the introduction of the 60:40 Policy in 1967 until Vision 2020, the latest National Science, Technology, and Innovation Policy (DSTIN), followed by the introduction of STEM in the PPPM 2013–2025, it was found that educational institutions, especially secondary schools, still failed to increase the participation of Malaysians in the STEM field (Kamarudin, n.d.; Mazalan, n.d.; Zainuddin, n.d.). It is not surprising that Malaysia's position in the TIMSS and PISA tests at the international level was only able to be ranked 57th out of 74 countries (OECD, 2010) and only increased 10 places to position 47 out of 78 in 2018 (OECD, 2019). This position is still far behind compared to the 11 developed countries that were also assessed in the international PISA and TIMSS (OECD, 2019). Similarly, Malaysia's position in the TIMSS 2023 and PISA 2022 assessments showed a decline compared to previous results. For example, in TIMSS 2023, Malaysia recorded an average score of 411 points in Mathematics and 426 points in Science, a decrease compared to 2019. Similarly, in PISA 2022, Malaysia only obtained an average score of 409 points in Mathematics, 416 points in Science, and 388 points in Reading, showing a decrease compared to 2018. Although Malaysia is still above the global average, the country is only ranked fourth among ASEAN countries in PISA 2022. This situation gives an impression of Malaysia's position, which is still lagging behind in the competition in the STEM field in education in the 21st century at the global level (Ministry of Education Malaysia, 2012). Statistics clearly prove that there is a lack of STEM implementation in the Malaysian education system, especially among secondary school students who are identified as still at a weak level (Noraini, 2019). In Malaysia, the implementation of STEM in the national education system has already entered its third wave (2021-2025). Ideally, STEM should have been successfully refined since its launch in the first wave (2013-2015) and

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second wave (2016–2020). However, the situation regarding STEM implementation itself is not yet comprehensive and does not meet the desired PPPM blueprint. But in the second and third waves of implementation, schools should focus on bringing technology into the lessons instead of just teaching STEM subjects, which they should have done in the first and second waves. In this way, it was discovered that the implementation of STEM in secondary schools in Malaysia does not yet have a concrete tool to check how well it has been carried out, especially when looking at it from the point of view of teachers who work in Malaysian secondary schools. In order to make up for the lack of existing tools, this study was very important. Its main goal was to validate the questionnaire that was made using the PLS-SEM method. By conducting this study, it contributes to the survey efforts to identify STEM implementation among secondary school teachers in Malaysia, thereby improving implementation in the future.

2. Literature

Since 1967 until the introduction of STEM in the 2013–2025 PPPM, there has not been much significant improvement, especially in meeting the national STEM enrolment that has been set. In fact, Malaysia is still plagued by the problem of a shortage of experts needed to fill the country's human resources in the STEM field (Kamarudin, n.d.; Mazalan, n.d.; Zainuddin, n.d.). This situation is due to the relatively slow momentum of development and the weak factors of the implementation of STEM education itself in schools (KPM, 2016). In the implementation context, among others, it was found that teachers lacked exposure to STEM-related knowledge (Roehrig et al., 2012). Teachers were found to have difficulty ensuring effective teaching due to the dynamics of rapid educational change (Copriady, 2014). This has led to a lack of knowledge, awareness, and interest in STEM-related teaching and learning (English & King, 2015; Shahali et al., 2017). Similarly, from the perspective of implementation input, it was found that teachers played a lesser role in conveying and providing exposure to STEM (Harian, 2019). Meanwhile, schools claimed that they were not given the opportunity to get involved, learn, and achieve access related to STEM, and this resulted in a lack of appreciation in implementation (KPM, 2016; Moreno et al., 2016; Rahayu et al., 2018). In addition, teachers' teaching and learning were hindered due to a lack of input on the curriculum, a lack of experience, and a lack of mastery of STEM pedagogical aspects (Ee, 2003; Ngali, 2009; Sidin, n.d.). Teachers were also identified as lacking in readiness, low competency levels, insignificant and low application of technology in teaching and learning (Ertmer & Ottenbreit-Leftwich, 2010; Moganashwari & Parilah, n.d.; Sang, 2011). In the process of implementing STEM in schools, it was found that the quality of teacher teaching is still low and has not reached the ideal level. This is made worse by problems with time management, getting materials, facilities, and teachers (KPM, 2013, 2016; Eroglu, 2016). This has led to a lack of integration of STEM education in real life (Bunyamin & Finley, n.d.). It was found that the responsible party lacks efforts in intensifying professional training on STEM education (Johnson & Sondergeld, 2016), in addition to lack of monitoring in implementation (KPM, 2013; Ederis, n.d.; Tan, 2010). As a result, low awareness creates constraints in terms of teacher acceptance, as well as raising issues of rejection by school management (KPM, 2013; MASTIC, 2008; OECD, 2012; Harian, 2019; Yusof et al., 2012). This situation is exacerbated when teachers' focus is disrupted due to conventional education doctrines orientated towards examinations (Adimin, 2005); in addition, teachers are still seen as weak in applying STEM elements, especially technology, and the implementation of STEM is considered a burden. Teachers are also described as more comfortable with conventional methods and claim to be willing to be burdened with clerical tasks outside the teaching field (Ahmad et al., 2015; Bourgonjon et al., 2013; Buabeng-Andoh, 2012; Sidek & Hasan, 2017; Singh & Chan, 2014; Teo, 2008). So, it's important that the implementation of STEM is supported by everyone, especially teachers, for a certain curriculum. This is because the teacher is responsible for the implementation's success (Mustafa, 2013).

3. Methodology

This study used a quantitative survey-type sample design, involving 825 teachers identified as having implemented STEM in seven district education offices (PPD) in the state of Sabah, namely PPD Kota Kinabalu, PPD Penampang, PPD Kudat, PPD Kunak, PPD Lahad Datu, PPD Semporna, and PPD Sandakan. The researcher used a proportional stratified sampling technique and selected a simple random sample. Before making this questionnaire, another one was made using Walker & Fraser (2005) instrument development procedure. This procedure had three main steps: the first step was to figure out what the main parts were; the second step was to add items to each part; and the third step was to do the actual study. This questionnaire used a five-point Likert-type scale to collect data. The process of obtaining the facial and content validity of the questionnaire had also been carried out previously, involving 13 experts, as detailed in Table 1. For data analysis, the researcher applied Partial Least Square Structural Equation Modelling (PLS-SEM) using SMARTPLS 3.2.3 software.

3.1. Questionnaire Instrument Formation Process

There are various views regarding the methods or procedures for properly forming an instrument. However, in the context of this study, the researcher applied the instrument development procedure by Walker & Fraser (2005) and detailed the three main stages of instrument formation as follows:

a). First Stage (Identifying the Main Components)

In the first stage, there are four steps used to identify and subsequently build the main constructs. The first step is to study the relevant literature in depth. A literature review is done by exploring various reference sources such as journals and articles from previous studies both domestically and internationally. This step is important to identify concepts and main components related to the context of the study. The second step is to study related instruments that have been built before. The purpose is to know the constructs and items that have been built. This is important because if there is a suitable construct or item, it can be modified according to the suitability of the context of this study. Next, the third step involves the process of obtaining relevant information, opinions and ideas from a panel of relevant experts. The fourth step involves the selection and determination of the main constructs based on a literature review, existing instruments and discussions (experts involved).

b). Second Stage (Construction of Items in Each Component)

The second stage involves the construction of items in each identified construct involving three main steps. The first step is to adapt several suitable items from existing instruments to be included as items in the new instrument. In addition, new items are also constructed based on literature and discussions for each identified construct. The second step involves the process of obtaining expert validity for the instrument that has been constructed. The experts that have been selected should be as many as possible in the relevant field of study. Therefore, the validity of the instrument through expert review is mainly done in confirming the suitability of items, construct compatibility and compatibility of measurement scales in the questionnaire which was built based on the exploration of literature covering theories, models and related aspects in past studies. The review process through expert evaluation is done by referring to individual experts with extensive experience in the field of study as listed in Table 1. The experts involved acted to review and provide approval, then confirmed the constructs and items using the instrument review form. Furthermore, quantitative analysis was conducted using the determination of content validity of Content Validity Ratio (CVR) and Content Validity Index (CVI) based on the Lawshe (1975). The findings of the expert analysis are detailed in the pilot study findings. Besides, for the strengthening of constructs and items, a construct validity analysis using the PLS-SEM approach. The assessment questionnaire instrument that had been reviewed by the expert was then analysed and revised based on the comments and suggestions for improvement given. All comments and criticisms obtained were taken into account, and improvements were made to the items in the instrument that was built. The third step was to conduct a pilot study. This pilot study was conducted to determine the validity and reliability aspects of the instrument that was built.

c). Third Stage (Conducting the Actual Study)

The third stage consists of two main steps. The first step involves administering the instrument that has been developed on a larger sample to further increase the validity and reliability of the instrument and enable it to be applied in an actual study. The second step involves validity testing. There are various methods that can be used to obtain the validity of an instrument. These methods can be classified into three main categories, namely content validity, criterion validity and construct validity. However, after examining the purpose of constructing the items produced, the researcher determined to obtain construct validity by further strengthening it with other forms of validity, namely face validity and content validity. Nunnally & Bernstein (1994) stated that construct validity is more suitable and appropriate to be used to validate the constructed instrument compared to other procedures. Therefore, in the context of this study, the researcher used the PLS-SEM approach. This technique was chosen to verify the construction of whether the constructs and items that have been selected really meet the statistical standards in the development of the instrument and can then be used in actual studies.

3.2. STEM Implementation Context Questionnaire (ICQ-STEM)

The ICQ-STEM was created using the context domain in the CIPP Model. This model focusses on the teacher's background knowledge and mastery of basic information about how to use STEM in teaching and learning, based on Ausubel's Receptive Learning Theory (1983). The determination of items is directed towards the scope of the respondent's knowledge regarding the background of teacher training and mastery of basic information. The

questionnaire of this study was constructed with taking into account all the context domain requirements in the CIPP Assessment Model based on Ausubel et al. (1983), that is, as representing the background or initial conditions regarding the implementation environment of STEM in teaching and learning. Evaluation of the implementation context in this study refers to the atmosphere or background of upgrading and mastering teachers' basic information about the implementation of STEM so that they can function in line with the concept, purpose, characteristics and role of teachers according to the STEM Implementation Guide in the teaching and learning document, as well as in line with the implementation goals in the PPPM 2013-2025. Rating implementation context This was done through a survey of teachers' perceptions of program implementers to assess information criteria that are mandatory requirements for the implementation of STEM in teaching and learning. The background of the teacher's training and mastery of basic information includes acquisition of knowledge and information about STEM education, aspects of mastery of concepts and objectives, implementation characteristics and the role of teachers in implementing STEM. ICQ-STEM items are positive items based on a five-point Likert scale.

Table 1. List of Expert Review Panel

Expert	Field of Expertise	Institution / Position	Experience
Expert 1	STEM education	National STEM Movement	30 Years
Expert 2	Science Studies	Science School	32 Years
Expert 3	Science Education	Faculty of Educational Psychology	30 Years
Expert 4	STEM education	Faculty of Educational Psychology	30 Years
Expert 5	STEM education	STEM Foundation Center	30 Years
Expert 6	Mathematics & Science Education	Department of Mathematical Sciences	10 Years
Expert 7	Science & Technical Education	Department of Technical Sciences	21 Years
Expert 8	STEM education	Senior STEM Teacher	10 Years
Expert 9	STEM education	Senior STEM Teacher	12 Years
Expert 10	STEM Model Development	Faculty of Education	12 Years
Expert 11	Statistics & Surveys	Malaysian Institute of Environment	19 Years
Expert 12	Statistics, Evaluation Measurement	Faculty of Education	38 Years
Expert 13	Statistics, Evaluation Measurement	Faculty of Education	29 Years

3.3. STEM Implementation Input Questionnaire (IIQ-STEM)

The IIQ-STEM tool was created using the input domain from the CIPP model. This is a resource that has been identified as a key factor in incorporating STEM elements into the way teachers teach and students learn in schools. This study's STEM implementation input questionnaire asks about things like facilities and equipment, teaching and learning materials, teachers' professional knowledge, teachers' skills in putting teaching and learning into practice, support, cooperation, and encouragement, as well as the strategies and methods used and how well the content of STEM implementation fits into teaching and learning. According to the STEM implementation guidance document, the parts of the STEM implementation input questionnaire were made with the goal of strengthening the use of STEM in teaching and learning in mind, as well as the ability to adapt to change. All IIQ-STEM items are positive.

3.4. STEM Implementation Process Questionnaire (IPQ-STEM)

The focus of the IPQ-STEM is based on the process domain in the CIPP Assessment Model, which refers to the planning decisions and a specific process applied to achieve the set goals (Idris, 2016). The components and items selected to represent the STEM implementation context questionnaire are referred to as decisions, procedures and implementation processes identified as contributing to the implementation of STEM in teaching and learning in secondary schools. The construction of this questionnaire is based on the set of procedures set by the Ministry of Education based on the STEM Implementation Guide in the Teaching and Learning document published by the Curriculum Development Division in 2016, as well as guided by the suitability of its goals in the PPPM 2013-2025. The guide clearly maps the implementation procedures and guidance on how to implement STEM in teaching and learning in secondary schools. All IPQ-STEM items are positive, based on a five-point Likert scale.

3.5. STEM Implementation Acceptance Questionnaire (IAQ-STEM)

IAQ-STEM was developed based on the product domain in the CIPP Model and is based on the Theory of Purposeful Behaviour (Fishbein & Ajzen, 1975). IAQ-STEM aims to survey teachers' perceptions as implementers in teaching and learning, covering teachers' beliefs, commitment and attitudes towards the implementation of STEM. The parts and items of IAQ-STEM were created by reading books and articles about a certain idea that fits with Fishbein &

Ajzen (1975), specifically products that help teachers agree to include STEM in their schools. When making the research questionnaire, teacher acceptance was the main factor that was used, along with the needs of the product domain in the CIPP Model. We found out how teachers felt about implementing STEM by asking them about their beliefs, commitment, and attitudes. These things showed how they felt about implementing STEM, which includes three parts of STEM education in teaching and learning: the STEM knowledge part, the STEM skills part, and the STEM values and ethics part. All items in this questionnaire are positive, based on a five-point Likert scale.

4. Research Findings

Validity and the reliability of this questionnaire were tested using SMART PLS Version 3.3.2 analysis in the Measurement Model. The PLS-SEM Measurement Model looks at three main aspects of construct validity to make sure it meets the statistical requirements. The first is figuring out the internal consistency reliability using the composite reliability (CR) and Cronbach's alpha criteria. The second is figuring out the convergent validity using the outer loading and average variance extracted criteria. And the third is figuring out the discriminant validity using the Fornell-Lacker, Cross Loading, and Heterotrait-Monotrait Ratio of correlations (HTMT) criteria. As shown in Table 2, the analysis results come from the PLS algorithm at the measurement model level. These results come from the ICQ-STEM, IIQ-STEM, IPQ-STEM and IAQ-STEM questionnaires. The criteria for internal consistency reliability were met because the value of alpha was above 0.70 (Nunally & Bernstein 1994). Meanwhile, AVE reading value reaches the level of 50% as recommended by (Hair et al., 2011, 2014, 2016). The AVE values for context (0.512), input (0.511), process (0.503), and implementation acceptance (0.557) are in line with the specified values.

Table 2. Convergent Validity Measurement Model

Instruments	Scale	Components	Outer Loadings	AVE	Composite Reliability	Cronbach Alpha
ICQ-STEM	Reflective	Concept	0.961	0.512	0.967	0.964
		Information	0.836			
		Features	0.770			
IIQ-STEM	Reflective	Knowledge	0.777	0.511	0.949	0.943
		Skills	0.903			
		Strategy	0.877			
IPQ-STEM	Reflective	Monitoring	0.775	0.503	0.955	0.950
		Coordination	0.737			
		Activities	0.897			
IAQ-STEM	Reflective	Planning	0.913	0.557	0.975	0.973
		Trust	0.871			
		Attitude	0.950			
		Commitment	0.933			

Table 3. Discriminant Validity Analysis - Cross Loadings

Item	1	2	3	4	Item	1	2	3	4
A1	0.210	0.545	0.271	0.137	C15	0.402	0.481	0.672	0.349
A10	0.344	0.717	0.374	0.243	C16	0.402	0.484	0.682	0.357
A11	0.350	0.719	0.356	0.242	C17	0.421	0.511	0.694	0.341
A13	0.432	0.787	0.403	0.289	C18	0.476	0.418	0.749	0.389
A14	0.457	0.587	0.383	0.297	C19	0.496	0.488	0.764	0.383
A15	0.492	0.574	0.402	0.340	C20	0.465	0.456	0.751	0.369
A16	0.414	0.735	0.435	0.353	C21	0.522	0.461	0.767	0.425
A17	0.454	0.790	0.476	0.384	C22	0.526	0.442	0.734	0.443
A18	0.527	0.754	0.502	0.373	C23	0.442	0.405	0.671	0.348
A19	0.417	0.753	0.481	0.317	C24	0.550	0.416	0.714	0.414
A2	0.259	0.609	0.290	0.203	C25	0.538	0.410	0.725	0.402
A20	0.546	0.716	0.484	0.431	C26	0.527	0.445	0.696	0.390
A21	0.468	0.762	0.477	0.361	C27	0.532	0.457	0.671	0.422
A22	0.499	0.810	0.467	0.399	C28	0.615	0.416	0.720	0.488
A23	0.508	0.815	0.481	0.379	C30	0.557	0.372	0.694	0.420
A25	0.539	0.790	0.489	0.398					

Item	1	2	3	4	Item	1	2	3	4
A26	0.533	0.816	0.512	0.392	C31	0.584	0.442	0.773	0.489
A27	0.560	0.753	0.540	0.367	C32	0.577	0.390	0.670	0.490
A28	0.505	0.575	0.460	0.418	D10	0.336	0.344	0.419	0.619
A3	0.322	0.696	0.357	0.240	D12	0.337	0.350	0.414	0.641
A30	0.575	0.635	0.528	0.380	D14	0.357	0.289	0.391	0.750
A31	0.548	0.801	0.556	0.393	D15	0.361	0.305	0.394	0.744
A5	0.337	0.680	0.344	0.197	D16	0.375	0.312	0.408	0.740
A6	0.325	0.699	0.373	0.228	D17	0.344	0.263	0.384	0.709
A7	0.318	0.650	0.356	0.213	D18	0.359	0.269	0.386	0.747
A8	0.315	0.647	0.345	0.225	D19	0.460	0.384	0.499	0.819
A9	0.339	0.691	0.345	0.254	D2	0.421	0.385	0.435	0.627
B17	0.591	0.429	0.386	0.239	D20	0.433	0.339	0.458	0.840
B18	0.632	0.402	0.403	0.261	D21	0.420	0.361	0.460	0.834
B19	0.708	0.434	0.443	0.308	D22	0.437	0.352	0.460	0.840
B20	0.686	0.409	0.469	0.300	D23	0.386	0.328	0.378	0.736
B21	0.710	0.463	0.497	0.337	D24	0.447	0.386	0.441	0.765
B22	0.761	0.442	0.490	0.360	D25	0.343	0.322	0.390	0.701
B23	0.659	0.533	0.497	0.397	D26	0.452	0.364	0.476	0.813
B24	0.719	0.391	0.470	0.372	D28	0.410	0.353	0.433	0.820
B25	0.772	0.462	0.464	0.384	D29	0.398	0.330	0.429	0.807
B26	0.765	0.419	0.441	0.388	D3	0.432	0.442	0.487	0.683
B27	0.727	0.453	0.497	0.372	D30	0.442	0.343	0.435	0.838
B34	0.747	0.449	0.607	0.446	D31	0.421	0.322	0.436	0.826
B35	0.701	0.436	0.508	0.399	D32	0.407	0.331	0.398	0.791
B36	0.734	0.449	0.602	0.410	D33	0.391	0.341	0.397	0.786
B37	0.780	0.455	0.594	0.471	D34	0.193	0.186	0.280	0.574
B38	0.664	0.439	0.587	0.389	D35	0.368	0.304	0.394	0.752
B39	0.754	0.436	0.608	0.437	D4	0.401	0.338	0.404	0.691
B40	0.731	0.442	0.620	0.444	D5	0.422	0.359	0.470	0.702
C10	0.535	0.349	0.668	0.381	D6	0.451	0.395	0.477	0.762
C11	0.521	0.381	0.666	0.385	D7	0.405	0.369	0.428	0.725
C13	0.541	0.366	0.704	0.399	D8	0.332	0.327	0.438	0.681
C14	0.412	0.470	0.687	0.364	D9	0.338	0.317	0.439	0.670

1. Input
2. Context
3. Process
4. Acceptance of Implementation

Table 4. Fornell-Larcker Criterion Analysis

INSTRUMENTS	IIQ-STEM	ICQ-STEM	IPQ-STEM	IAQ-STEM
IIQ-STEM	0.715			
ICQ-STEM	0.617	0.715		
IPQ-STEM	0.716	0.608	0.709	
IAQ-STEM	0.525	0.450	0.569	0.746

The results of the analysis in Table 3 show that there is no problem with cross-loadings in the measurement of this model. Next, the results of the Fornell-Larcker Criterion test in Table 5 confirm that the double value of AVEs (diagonal value) is greater than the correlation coefficient relationship (not diagonal value), indicating that discriminant validity is adequate (Fornell & Larcker, 1981) except for input with process. However, the analysis of the HTMT results (Table 5) proves that discriminant validity has been met; this is because the HTMT approach as a technique for determining discriminant validity is better than the Fornell-Larcker and cross-loading criteria (Henseler et al., 2009). Therefore, overall, the measurement model for this questionnaire is adequate in determining the validity of the study construct because it has been proven to meet the internal consistency reliability aspect based on the composite reliability and Cronbach's alpha criteria.

Meets convergent validity based on outer loading and average variance extracted criteria and meets discriminant validity based on Fornell-Lacker, Cross Loading and Heterotrait-Monotrait Ratio (HTMT) criteria.

Table 5. Analysis of Heterotrait-Monotrait Ratio (HTMT)

	1	2	3	4	5	6	7	8	9	10	11	12
2	0.564											
3	0.535	0.624										
4	0.552	0.487	0.483									
5	0.429	0.444	0.429	0.745								
6	0.573	0.784	0.592	0.494	0.413							
7	0.672	0.499	0.573	0.472	0.435	0.446						
8	0.488	0.522	0.734	0.360	0.319	0.528	0.490					
9	0.624	0.342	0.408	0.447	0.346	0.536	0.565	0.388				
10	0.833	0.646	0.650	0.568	0.538	0.579	0.746	0.535	0.549			
11	0.411	0.487	0.393	0.327	0.236	0.726	0.314	0.401	0.510	0.352		
12	0.457	0.479	0.458	0.785	0.898	0.417	0.457	0.322	0.334	0.582	0.250	
13	0.634	0.671	0.695	0.506	0.488	0.561	0.674	0.573	0.430	0.803	0.328	0.518

1. Activities
2. Features
3. Teacher Skills
4. Trust
5. Commitment
6. Concept & Purpose
7. Monitoring
8. Professional Knowledge
9. Coordination
10. Planning
11. Information Acquisition
12. Attitude
13. Strategies & Methods

5. Discussion

Over five decades of implementing STEM education in Malaysia, there are still deficiencies and challenges within the Malaysian education system that justify the need for this study. Various policies and initiatives have been highlighted by the government, starting with the introduction of policies such as the 60:40 Policy, leading to Vision 2020, and more recently, the Malaysia Education Development Plan (PPPM) 2013–2025, all aimed at establishing a strong foundation in the Malaysian education system. Unfortunately, to this day, the expected outcomes in the implementation of STEM education, particularly among secondary school educators, remain an ongoing public discussion that has yet to be resolved. This is evidenced by Malaysia's performance competency, which is often discussed for its weak achievement levels, particularly in aspects of international education benchmarks such as TIMSS and PISA, which have only managed to reach a deteriorating and static state. This situation is far surpassed by most ASEAN countries and even more so by developed countries. This situation is certainly an important indicator that there are issues in the implementation of STEM in secondary schools that have not been resolved thoroughly and efficiently. In fact, the issue of the lack of experts in the STEM field in Malaysia has been reported, partly due to the suboptimal quality of STEM implementation, particularly at the secondary school level (Kamarudin, n.d.; Mazalan, n.d.; Zainuddin, n.d.). The issue that is often raised is the lack of readiness among educators in integrating technological elements during the teaching process, in addition to being accustomed to conventional teaching methods that create a comfort zone among teachers. Therefore, through this study, an important contribution is made by developing and validating a comprehensive set of instruments suitable for the context of STEM education in Malaysia, namely, ICQ-STEM, IIQ-STEM, IPQ-STEM, and IAQ-STEM. The foundation of the development of this instrument is based on the CIPP program evaluation model, grounded in four main domains of study, namely, context, input, process, and product aspects. The results of the statistical analysis applying the PLS-SEM approach in this study successfully demonstrated the validity and reliability aspects of the instrument as a legitimate measurement

tool to be used in evaluating the implementation of STEM, particularly among secondary school teachers in Malaysia. The ICQ-STEM instrument has been successfully developed to assess the aspects of teachers' knowledge background and training. This aspect is emphasized as important in determining the success of STEM implementation at the school level (Roehrig et al., 2012; Shahali et al., 2017). For the IIQ-STEM and IPQ-STEM instruments, it is essential to evaluate the aspects of resource preparation and the STEM implementation process in order to explore the weaknesses identified as the main constraints in its implementation in secondary schools (KPM, 2016; Moreno et al., 2016). Next, the IAQ-STEM instrument is capable of examining the role of teachers as implementers in secondary schools by assessing their acceptance based on the three main domains proposed by Fishbein & Ajzen (1975), namely the aspects of belief, commitment, and attitude through the Theory of Planned Behavior. This study has significant implications, particularly in providing a standardized research tool to holistically assess the perspective of teachers as implementers of the STEM education program in Malaysian secondary schools. This study clearly highlights that the elements of attitude, organizational support, and teacher competence are crucial factors to consider if one aims to achieve an ideal implementation of STEM. Through the development of this instrument, stakeholders can be provided with an effective alternative measurement tool to focus their efforts accurately towards the improvement of STEM implementation in Malaysia. However, this study has limitations in terms of context, as it was only conducted within the educational context of the State of Sabah. Therefore, to determine the feasibility of this instrument being applicable to various different backgrounds, the aspects of validity and reliability of the instrument are relevant to be extended to involve different contexts, including among primary school teachers, involving various states in Malaysia, and considering the international environmental situation. In conclusion, this study successfully developed and statistically tested a comprehensive set of instruments to assess the implementation of STEM among secondary school teachers in Malaysia. With this effort, the ICQ-STEM, IIQ-STEM, IPQ-STEM, and IAQ-STEM instruments have been identified not only as significant contributions to the field of educational research but also as useful guidelines for stakeholders in making policy decisions, particularly in the area of secondary school STEM education in Malaysia.

6. Conclusion

The PLS-SEM approach proved that the validity and reliability aspects of ICQ-STEM, IIQ-STEM, IPQ-STEM, and IAQ-STEM were successfully achieved. The results of the internal consistency reliability analysis based on the composite reliability and Cronbach's alpha criteria have been met. Similarly, the convergent validity aspect, based on the outer loading and average variance extracted criteria, has also been met. You can also use the Fornell-Lacker, Cross-Loading, and Heterotrait-Monotrait Ratio (HTMT) to show that discriminant validity analysis works. Thus, it can be concluded that ICQ-STEM, IIQ-STEM, IPQ-STEM, and IAQ-STEM have been statistically proven to be useful for reviewing the implementation of STEM among secondary school teachers in Malaysia. These findings have important implications for educational practice, particularly in providing reliable assessment tools to policymakers, researchers, and school administrators to evaluate and strengthen STEM initiatives at the secondary school level. The strength of the instrument testing conducted statistically serves as a robust tool to contribute towards the improvement of STEM implementation in the teaching of secondary school teachers in Malaysia. However, from the contextual aspect, it is acknowledged that this study has limitations, namely that it only focuses on the secondary school group, which may have certain limitations for generalisation to other research contexts. Therefore, for future studies, it is suggested that the testing of this instrument also consider other aspects such as demographic background, diversity in educational levels, and compatibility in the context of international education. In conclusion, the success in the development and testing of the ICQ-STEM, IIQ-STEM, IPQ-STEM, and IAQ-STEM instruments demonstrates the high value of the research results, which can be practically beneficial in strengthening STEM education in Malaysia through continuous and systematic assessment practices.

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References

- (KPM), M. of E. M. (2013). *Pelan Pembangunan Pendidikan Malaysia 2013–2025*. KPM.
- (KPM), M. of E. M. (2016). *Laporan Tahunan PPPM 2013–2025*. KPM.
- (MASTIC), M. S. and T. I. C. (2008). *National survey of research and development (R&D)*. <https://mastic.mestec.gov.my/sti-survey-content-spds/national-survey-research-and-development-rd-2008>
- (OECD), O. for E. C. and D. (2012). *PISA 2012 Country note – United States*. <http://www.oecd.org/pisa/keyfindings/PISA-2012-results-US.pdf>
- Adimin, J. (2005). National assessment system: A new perspective. *Educator*, 21/2006.
- Ahmad, A. R. M., Ahmad, A. R., Saleha, A., & Abd Hadi, N. A. (2015). Teacher competence in the application of information and communication technology (ICT) in teaching and learning. In *Proceedings of the 7th International Seminar on Regional Education*.
- Ausubel, D., Novak, J., & Hanesian, H. (1983). *Educational psychology: A cognitive point of view*. Trillas.
- Bourgonjon, J., De Grove, F., De Smet, C., Van Looy, J., Soetaert, R., & Valcke, M. (2013). Acceptance of game-based learning by secondary school teachers. *Computers & Education*, 67, 21–35. <https://doi.org/10.1016/j.compedu.2013.02.014>
- Buabeng-Andoh, C. (2012). Factors influencing teachers' adoption and integration of information and communication technology into teaching: A review of the literature. *International Journal of Education and Development Using Information and Communication Technology*, 8(1), 136–155.
- Bunyamin, M. A. H., & Finley, F. (n.d.). STEM education in Malaysia: Reviewing the current physics curriculum. *International Conference of Association for Science Teacher Education (ASTE)*.
- Copriady, J. (2014). Teachers' competence in the teaching and learning of practical chemistry. *Mediterranean Journal of Social Sciences*.
- Ederis, Y. (n.d.). Assessment in mathematics: Issues and challenges. *National Seminar of the Malaysian Association for Mathematics Education (PPMM)*.
- Ee, A. M. (2003). *Educational science: Professional knowledge and skills*. Fajar Bakti Sdn. Bhd.
- English, L. D., & King, D. T. (2015). STEM learning through engineering design: Fourth grade students' investigations in aerospace. *International Journal of STEM Education*, 2, 14.
- Eroglu, S. (2016). High school students' perceptions towards environmental issues: A phenomenological study. *The Online Journal of New Horizons in Education*, 6(4), 64–74.
- Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, 42(3), 255–284. <https://doi.org/10.1080/15391523.2010.10782551>
- Fishbein, M., & Ajzen, I. (1975a). *Beliefs, attitudes, intentions and behavior: An introduction to theory and research*. Addison-Wesley.
- Fishbein, M., & Ajzen, I. (1975b). *Beliefs, attitudes, intentions and behaviors*. Addison Wesley Publishing Company.
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39–50.
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2014). *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage.
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2016). *A primer on partial least squares structural equation modeling (PLS-SEM)* (2nd ed.). Sage.
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed, a silver bullet. *Journal of Marketing Theory and Practice*, 19(2), 139–151. <https://doi.org/10.2753/MTP1069-6679190202>
- Harian, B. (2019). *Ibu bapa beri isyarat salah antara punca STEM merosot*.

<https://www.bharian.com.my/berita/pendidikan/2019/03/541952/ibu-bapa-beri-isyarat-salah-antara-punca-stem-merosot>

- Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The use of partial least square path modeling in international marketing. In R. R. Sinkovics & P. N. Ghauri (Eds.), *Advances in International Marketing* (Vol. 20, pp. 277–320). Emerald.
- Idris, N. (2016). *Penilaian pelaksanaan pentaksiran berasaskan sekolah dalam kalangan guru*. Universiti Pendidikan Sultan Idris.
- Johnson, C. C., & Sondergeld, T. A. (2016). Effective STEM professional development. In C. C. Johnson, E. E. Peters-Burton, & T. J. Moore (Eds.), *STEM road map: A framework for integrated STEM education* (pp. 203–210). Routledge Taylor & Francis Group.
- Kamarudin, K. (n.d.). Skill shortage is a challenge for industry 4.0. *Malaysiakini*. <https://www.malaysiakini.com/news/458549>
- Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology*, 28(4), 563–575. <https://doi.org/10.1111/j.1744-6570.1975.tb01393.x>
- Mazalan, R. (n.d.). Women in science and technology are still lacking. *Berita Harian Online*. <https://www.bharian.com.my/wanita/lain-lain/2019/03/537622/wanita-dalam-bidang-sains-dan-teknologi-masih-kurang>
- Moganashwari, K., & Parilah, M. S. (n.d.). Knowledge, attitude, and use of ICT among ESL teachers. *Proceedings of the Global Summit on Education*.
- Moreno, N. P., Tharp, B. Z., Vogt, G., Newell, A. D., & Burnett, C. A. (2016). Preparing students for middle school through after-school STEM activities. *Journal of Science Education and Technology*, 25(6), 889–897. <https://doi.org/10.1007/s10956-016-9635-2>
- Mustafa, S. I. S. (2013). Teaching guidance practices of lecturers and supervising teachers in the practicum mentoring program and its impact on the quality of trainee teachers. *Malaysian Journal of Education*, 38(1), 71–78.
- Ngali, N. A. M. (2009). *Teachers' readiness for teaching practical skills in the vocational education curriculum*. Tun Hussein Onn University.
- Noraini, I. (2019). Experts: Fewer STEM students will affect nation's talent pool. *The Star Online*. <https://www.thestar.com.my/news/nation/2019/03/18/experts-fewer-stem-students-will-affect-nations-talent-pool>
- Nunnally, J. C., & Bernstein, I. H. (1994). The assessment of reliability. In *Psychometric Theory* (Vol. 3).
- OECD. (2010). *Education at a Glance 2010: OECD Indicators*. OECD Publishing. <https://doi.org/10.1787/eag-2010-en>
- OECD. (2019). *The Future of Education and Skills 2030: OECD Learning Compass 2030*. OECD Publishing. <https://doi.org/10.1787/5f14d11f-en>
- Rahayu, T., Syafril, S., Pahrudin, A., Satar, I., Osman, K., Halim, L., & Yaumas, N. E. (2018). *Mini review: Solutions to improve teacher quality in STEM learning in secondary schools*. National University of Malaysia.
- Roehrig, G. H., Moore, J. T., Wang, H.-H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics*, 112(1), 31–44. <https://doi.org/10.1111/j.1949-8594.2011.00113.x>
- Sang, M. S. (2011). *Classroom management and behavior* (3rd ed.). Multimedia Publishing Sdn. Bhd.
- Shahali, E. H. M., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2017). STEM learning through engineering design: Impact on middle secondary students' interest towards STEM. *EURASIA Journal of Mathematics, Science and Technology Education*, 13(5), 1189–1211. <https://doi.org/10.12973/eurasia.2017.0135a>
- Sidek, S., & Hasan, A. (2017). STEM learning through engineering design: Impact on middle secondary students' interest towards STEM. *EURASIA Journal of Mathematics, Science and Technology Education*, 13(5), 1189–

1211.

- Sidin, R. (n.d.). Innovation in teaching methods: Experience at the National University of Malaysia. *Proceedings of the National Conference on Teaching and Learning in Higher Education*.
- Singh, T. K. R., & Chan, S. (2014). Teacher readiness on ICT integration in teaching-learning: A Malaysian case study. *International Journal of Asian Social Science*, 4(7), 874–885.
- Tan, A. M. (2010). *Pentaksiran berasaskan sekolah (PBS) di Malaysia*. Universiti Kebangsaan Malaysia.
- Teo, T. (2008). Assessing the computer attitudes of students: An Asian perspective. *Journal of Computers in Human Behavior*, 24, 1634–1642. <https://doi.org/10.1016/j.chb.2007.06.005>
- Walker, S., & Fraser, B. (2005). Development and validation of an instrument assessing distance education learning environments in higher education: The distance learning environment survey (DELES). *Learning Environments Research: An International Journal*, 8(3), 289–308. <https://doi.org/10.1007/s10984-005-6271-3>
- Yusof, N., Hashim, R. A., Badusah, J., Konting, M. M., & Kian, C. K. (2012). Communicating change: The Five Sentiments of Change perspective. *Jurnal Pengurusan*, 35(September), 87–96. <https://doi.org/10.17576/pengurusan-2012-35-08>
- Zainuddin, M. Z. (n.d.). Engineering, ICT and business fields are among the most sought after. *Berita Harian Online*. <https://www.bharian.com.my/bisnes/lain-lain/2018/12/508332/bidang-kejuruteraan-ict-dan-perniagaan-antara-paling-dikehendaki>