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Validation of the STEM career interest measurement model among secondary school students using confirmatory factor analysis

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ABSTRACT

This study aimed to validate the measurement model of STEM Career Interest among secondary school students using first-order and second-order Confirmatory Factor Analysis. A quantitative survey design was employed involving 384 Form One students from secondary schools in Perak, Malaysia. The STEM Career Interest construct was measured using 44 items representing four dimensions with Science Career Interest, Technology Career Interest, Engineering Career Interest and Mathematics Career Interest. Data were analysed using IBM SPSS and IBM SPSS AMOS version 30. The first-order CFA results showed that all items achieved satisfactory standardised factor loadings, ranging from 0.783 to 0.869 for Science, 0.764 to 0.847 for Technology, 0.804 to 0.887 for Engineering and 0.829 to 0.889 for Mathematics. Reliability and convergent validity were also supported, with Cronbach's alpha values ranging from 0.954 to 0.971, Composite Reliability values ranging from 0.954 to 0.971 and Average Variance Extracted values ranging from 0.654 to 0.753. The modified CFA models demonstrated acceptable model fit for Science, Technology and Engineering, while the Mathematics model showed acceptable comparative and incremental fit despite marginal RMSEA. The second-order CFA further supported STEM Career Interest as a higher-order construct, with acceptable fit indices, ChiSq/df = 2.240, RMSEA = 0.057, CFI = 0.939, IFI = 0.939 and TLI = 0.936. Overall, the findings provide empirical evidence that the STEM Career Interest measurement model is valid and reliable for assessing domain-specific STEM career interest among Malaysian secondary school students.

Keywords: STEM career interest, confirmatory factor analysis, measurement model, construct validity, STEM education, secondary school students

INTRODUCTION

STEM education has become an increasingly important objective in education because science, technology, engineering and mathematics are linked to innovation, digital transformation and future workforce development (UNESCO, 2017). STEM education is important when it comes to preparing students to enter science and technology-related fields because it prepares them to meet the ever-changing needs of the education, employment and labour force globally (Idris et al., 2024; Samngamjan et al., 2026; UNESCO, 2017). Therefore, students' interest in STEM-related careers should be taken seriously as career interest may influence their academic participation, subject selection and future participation in STEM pathways (Kier et al., 2014; Lent et al., 1994).

Career interest is an important psychological construct to study as it is believed that students are inclined to be interested in certain academic and occupation options (Lent et al., 1994). As per Social Cognitive Career Theory, career-related interest is the result of self-efficacy, expectation of success in career as a result of learning, and context (Lent et al., 1994). In STEM education, students' confidence, exposure to, and perceived value of STEM subjects can influence students' desire to pursue STEM career opportunities as a career path (Hiğde & Aktamış, 2022; Kier et al., 2014; Roller et al., 2020). So, understanding STEM career interest among students in secondary school is important as it is at this age when students start to understand more clearly how they are looking forward to their academic and career pathway (Kier et al., 2014; Lent et al., 1994). However, achieving the accurate measurement of STEM career interest is a methodological issue in STEM education research.

The current STEM career interest instruments have contributed to science education but there are still limitations when applied to different educational and cultural contexts. Firstly, the STEM career interest instruments have been developed in

Western or non-Malaysian countries and the factor structure of that instrument may not accurately reflect the educational background of students in the Malaysian secondary school (Kier et al., 2014; Koyunlu Ünlü et al., 2016). Second, some of the existing studies have used STEM career interest instruments mainly as outcome measures without any evidence of validity of the measurement structure for the sample examined (Ardianto et al., 2023; Cheung et al., 2024). Third, STEM career interest is often a general construct and students may show different levels of interest in science, technology, engineering and mathematics (Kier et al., 2014; Playton et al., 2024).

These limitations highlighted the need for further validation of STEM career interest instruments in the field of secondary education. The STEM Career Interest Survey by Kier et al. (2014) has been the most widely used instrument to measure students' interest in STEM careers. The instrument measures STEM career interest for four disciplines (Kier et al., 2014): Science Career Interest, Technology Career Interest, Engineering Career Interest and Mathematics Career Interest. While the STEM-CIS has been adapted and validated in Turkey and Indonesia by different researchers, it still needs to be studied and verified in Malaysia because measurement properties may differ by student groups and educational systems and cultures (Ardianto et al., 2023; Koyunlu Ünlü et al., 2016). It is thus crucial to test the STEM-CIS in Malaysian lower secondary school culture before it is used in any other statistical analysis or educational intervention. The gender and educational experience of students also shape students' STEM career choice and participation. Patrinopoulos et al. (2022) highlighted that education plays an important role in shaping gender differentiation in STEM career choice, so STEM career interest should also be seen from an educational and psychological perspective. This is also relevant in Malaysia, where STEM participation is a concern and students' interest in STEM may be influenced by educational exposure, motivation, career awareness and context (Idris et al., 2023, 2024). Therefore, a robust STEM career interest measurement model should be in place for future studies on students' STEM career orientation across different demographic and educational groups.

Confirmatory Factor Analysis is a good way to validate measuring models since it allows researchers to test whether the material is in the model or not (Hair Jr et al., 2019; Kline, 2016). CFA is also useful to evaluate factor loadings, model fit, convergent validity and construct reliability which are important to validate a measurement model (Cheung et al., 2024; Hair Jr et al., 2019). In this study, the STEM Career Interest construct in first-order CFA using four dimensions, Science Career Interest, Technology Career Interest, Engineering Career Interest and Mathematics Career Interest. Second-order CFA was also used to see whether these four first-order dimensions could be represented by a broader higher-order STEM Career Interest construct.

Although previous studies have shown the usefulness of STEM-CIS, there is limited evidence for the validity of its four-domain structure as a valid first-order and second-order measurement model among lower secondary school students in Malaysia. This is an important gap since measurement validity should be established in relation to psychological, educational or demographic factors before investing in STEM career interest. Therefore, this study aims to validate the STEM Career Interest measurement model among Malaysian secondary school students with first-order and second-order Confirmatory Factor Analysis.

LITERATURE REVIEW

STEM career interest refers to students' tendency, preference and motivation to consider future careers related to science, technology, engineering and mathematics. In the context of career development, interest is viewed as an important psychological factor because it may influence students' academic choices, career exploration and persistence in future occupational pathways. Social Cognitive Career Theory explains that career interest is shaped by self-efficacy, outcome expectations, learning experiences and contextual influences, making it highly relevant in understanding students' orientation toward STEM-related careers (Lent et al., 1994).

In STEM education, career interest is not limited to students' enjoyment of science or mathematics subjects, but also reflects their perceived possibility of pursuing STEM-related occupations in the future. Students may demonstrate different levels of interest across specific STEM domains because science, technology, engineering and mathematics involve different learning experiences, skills and career images. Therefore, STEM career interest should be examined as a multidimensional construct rather than as a single general preference toward STEM. Kier et al. (2014) reported that the STEM Career Interest Survey can function both as a general STEM career interest measure and as four discipline-specific subscales involving science, technology, engineering and mathematics.

This multidimensional understanding is important in secondary education because students at this stage begin to develop clearer academic and career aspirations. The STEM-CIS was specifically designed to measure STEM career interest among secondary-level students and has been identified as useful for research, evaluation and professional development. Therefore, validating STEM career interest among secondary school students is important because it allows researchers and educators to understand whether students' interest is stronger in certain STEM domains compared with others.

STEM Career Interest Survey

The STEM Career Interest Survey, also known as STEM-CIS, was developed by Kier et al. (2014) to measure students' career interest in science, technology, engineering and mathematics. The instrument contains four subscales, namely Science Career Interest, Technology Career Interest, Engineering Career Interest and Mathematics Career Interest. Each subscale represents a specific STEM domain, allowing researchers to examine students' interest either separately by domain or collectively as an overall STEM career interest construct.

The STEM-CIS is particularly suitable for studies involving secondary school students because it was developed to measure interest in STEM classes and careers among middle school students. The instrument contains 44 items and uses a five-point Likert scale, with its theoretical foundation linked to Social Cognitive Career Theory. This makes the STEM-CIS appropriate for studies that examine students' interest in STEM careers from both educational and psychological perspectives.

Previous studies have continued to use and validate the STEM-CIS in different educational contexts. Ardianto et al. (2023) validated the STEM-CIS using the Rasch measurement model among 572 junior high school students and reported that the items demonstrated good measurement quality, item validity and reliability. A recent psychometric study in the Indonesian context also examined the STEM-CIS and highlighted the importance of reporting psychometric evidence when the instrument is used in a new educational setting. These studies show that although the STEM-CIS is an established instrument, continuous validation remains necessary when it is applied across different samples, cultures and schooling systems.

In the Malaysian context, STEM career interest has also been examined using Kier et al.'s STEM-CIS framework. A Malaysian study among secondary school students highlighted that the STEM-CIS is relevant for examining students' interest across science, technology, engineering and mathematics within the country's STEM education agenda. However, additional validation using Confirmatory Factor Analysis is still important to confirm whether the four-domain structure fits the Malaysian secondary school sample in the present study.

Multidimensional Structure of STEM Career Interest

STEM career interest is best understood as a multidimensional construct because students may not show equal interest in all STEM fields. For instance, a student may have strong interest in technology but moderate interest in engineering, or strong interest in science but lower interest in mathematics. Kier et al. (2014) found that the STEM-CIS demonstrated both a strong general factor and four strong discipline-specific subscales, supporting the idea that the instrument may be analysed as separate STEM domains or as a broader STEM career interest measure.

This multidimensional structure provides a strong theoretical justification for conducting both first-order and second-order Confirmatory Factor Analysis. First-order CFA allows each domain, namely Science Career Interest, Technology Career Interest, Engineering Career Interest and Mathematics Career Interest, to be tested individually as separate latent constructs. Second-order CFA allows these four first-order dimensions to be tested under a broader higher-order construct known as STEM Career Interest. In the present study, this approach is appropriate because the uploaded CFA analysis shows that each STEM domain was examined individually before being tested as part of the overall STEM Career Interest construct.

The use of a second-order structure is also conceptually meaningful because STEM is often treated as an integrated educational and career field, even though it consists of discipline-specific domains. Therefore, a valid STEM Career Interest measurement model should be able to demonstrate that science, technology, engineering and mathematics are distinct enough to be measured separately, but sufficiently related to represent a broader STEM career interest construct.

Confirmatory Factor Analysis in Measurement Validation

Confirmatory Factor Analysis is widely used to validate measurement models because it tests whether observed items represent the proposed latent constructs. In contrast to exploratory analysis, CFA is theory-driven and is suitable when the researcher already has an expected structure of the construct. This is relevant to the present study because the STEM Career Interest model is theoretically based on four domains: science, technology, engineering and mathematics.

In measurement validation, CFA enables researchers to examine several important psychometric indicators, including factor loadings, model fit, construct reliability and convergent validity. Cheung et al. (2024) emphasised that convergent validity in structural equation modelling should be examined through a CFA measurement model in which indicators are related to their intended constructs. This means that each item should load strongly on the dimension it is supposed to measure.

CFA is also important because it helps researchers evaluate whether the proposed model fits the empirical data. Model fit indices such as ChiSq/df, RMSEA, CFI, IFI and TLI are commonly used to determine whether the measurement model achieves an acceptable level of fit. In the context of this study, these indices are necessary to evaluate whether the four STEM Career Interest dimensions are statistically valid and suitable for further analysis. The uploaded CFA results show that the model fit indices were examined for Science, Technology, Engineering and Mathematics Career Interest, and modification was conducted only where theoretically justified.

Reliability and convergent validity are also essential in CFA-based validation studies. Composite Reliability is used to assess the internal consistency of items within a latent construct, while Average Variance Extracted is used to assess whether the construct explains sufficient variance among its indicators. Cheung et al. (2024) recommended clear reporting of reliability, convergent validity and discriminant validity when using structural equation modelling. Therefore, in validating STEM Career Interest, the reporting of factor loadings, model fit, Composite Reliability and AVE is important to demonstrate that the instrument is psychometrically sound.

METHODOLOGY

This study employed a quantitative survey design to validate the measurement model of STEM Career Interest among secondary school students. The sample consisted of 384 Form One students from secondary schools in Perak, Malaysia. The STEM Career Interest construct was measured using the STEM Career Interest Survey developed by Kier et al. (2014). The instrument consisted of 44 items representing four dimensions: Science Career Interest, Technology Career Interest, Engineering Career Interest and Mathematics Career Interest. Each dimension contained 11 items. **Table 1** presents the dimensions and items included in the STEM Career Interest Instrument. **Table 2** summarises the model fit criteria adopted in this study.

Table 1. Dimension and items of the STEM career interest instrument

Construct	Dimension	Number of Items	Item Code
STEM Career Interest	Science Career Interest	11	KS1–KS11
STEM Career Interest	Technology Career Interest	11	KT1–KT11
STEM Career Interest	Engineering Career Interest	11	KE1–KE11
STEM Career Interest	Mathematics Career Interest	11	KM1–KM11

Table 2. Model fit criteria

Fit Category	Fit Index	Recommended Threshold
Parsimonious fit	ChiSq/df	< 5.00
Absolute fit	RMSEA	< 0.08
Comparative fit	CFI	> 0.90
Incremental fit	IFI	> 0.90
Tucker-Lewis fit	TLI	> 0.90

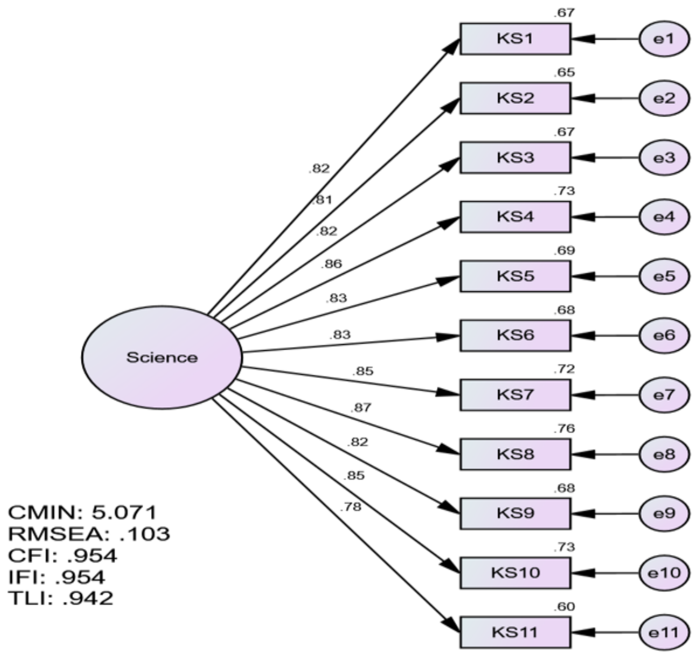

Figure 1. Initial first-order CFA model for science career interest (Source: Authors' own elaboration, based on the CFA Results)

Data were analysed using IBM SPSS and IBM SPSS AMOS version 30. First-order Confirmatory Factor Analysis was conducted to examine the measurement quality of each STEM Career Interest dimension separately. Subsequently, second-order CFA was performed to determine whether Science, Technology, Engineering and Mathematics Career Interest could be represented by a broader higher-order STEM Career Interest construct.

The measurement model was evaluated using ChiSq/df, RMSEA, CFI, IFI and TLI. Cronbach's alpha and Composite Reliability were used to assess reliability, while Average Variance Extracted was used to assess convergent validity. The accepted criteria were ChiSq/df below 5.00, RMSEA below 0.08, CFI, IFI and TLI above 0.90, CR above 0.70 and AVE above 0.50. Model modification was conducted only when supported by both Modification Indices and theoretical justification.

FINDINGS

Figure 1 and **Table 3** present the initial first-order CFA model for Science Career Interest. The initial model showed that the comparative and incremental fit indices were acceptable, with CFI = 0.954, IFI = 0.954 and TLI = 0.942. However, the parsimonious and absolute fit indices did not meet the recommended thresholds, as indicated by ChiSq/df = 5.071 and RMSEA = 0.103. These results suggest that although the Science Career Interest items generally represented the construct, the initial model required further refinement to improve overall model fit. Therefore, model modification was considered based on Modification Indices and theoretical justification.

Table 3. Goodness-of-fit indices for the initial science career interest CFA model

Category	Fit Index	Index Value	Research Finding
Parsimonious Fit	ChiSq/df	5.071	Did not meet the required threshold
Absolute Fit	RMSEA	0.103	Did not meet the required threshold
Comparative Fit	CFI	0.954	Met the required threshold
Incremental Fit	IFI	0.954	Met the required threshold
Tucker-Lewis Fit	TLI	0.942	Met the required threshold

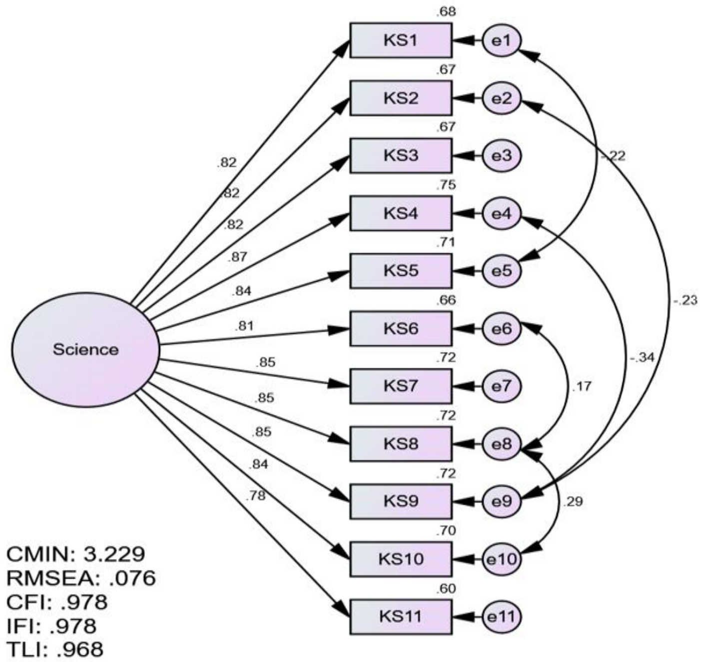

Figure 2. Modified first-order CFA model for science career interest (Source: Authors' own elaboration, based on the CFA Results)

Table 4. Goodness-of-fit indices for the modified science career interest CFA model

Category	Fit Index	Index Value	Research Finding
Parsimonious Fit	ChiSq/df	3.229	Met the required threshold
Absolute Fit	RMSEA	0.076	Met the required threshold
Comparative Fit	CFI	0.978	Met the required threshold
Incremental Fit	IFI	0.978	Met the required threshold
Tucker-Lewis Fit	TLI	0.968	Met the required threshold

Figure 2 and **Table 4** present the modified first-order CFA model for Science Career Interest. After model modification, all fit indices achieved the recommended thresholds, indicating a substantial improvement in model fit. The ChiSq/df value decreased to 3.229, while the RMSEA value improved to 0.076, demonstrating acceptable parsimonious and absolute fit. In addition, the comparative and incremental fit indices also improved, with CFI = 0.978, IFI = 0.978 and TLI = 0.968. These results indicate that the modified Science Career Interest model achieved satisfactory goodness-of-fit and was therefore retained for subsequent reliability and validity assessment.

Figure 3 and **Table 5** present the initial first-order CFA model for Technology Career Interest. The initial model demonstrated acceptable comparative and incremental fit, as shown by CFI = 0.968, IFI = 0.968 and TLI = 0.960. However, the ChiSq/df value of 3.456 and RMSEA value of 0.080 indicated that the model did not fully achieve the required fit criteria based on the threshold adopted in this study. These findings suggest that the initial Technology Career Interest model was generally acceptable but still required refinement to obtain a stronger overall model fit. Therefore, model modification was considered by referring to the Modification Indices and theoretical justification related to item content.

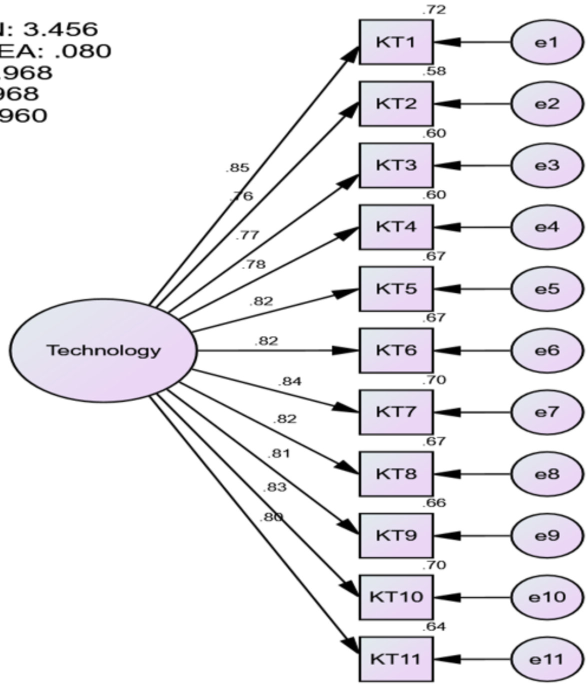

Figure 3. Initial first-order CFA model for technology career interest (Source: Authors' own elaboration, based on the CFA Results)

Table 5. Goodness-of-fit indices for the initial technology career interest CFA model

Category	Fit Index	Index Value	Research Finding
Parsimonious Fit	ChiSq/df	3.456	Did not meet the required threshold
Absolute Fit	RMSEA	0.080	Did not meet the required threshold
Comparative Fit	CFI	0.968	Met the required threshold
Incremental Fit	IFI	0.968	Met the required threshold
Tucker-Lewis Fit	TLI	0.960	Met the required threshold

Figure 4 and **Table 6** present the modified first-order CFA model for Technology Career Interest. After model modification, all fit indices achieved the recommended thresholds, indicating that the modified model demonstrated satisfactory goodness-of-fit. The ChiSq/df value improved to 2.319, while the RMSEA value decreased to 0.059, showing acceptable parsimonious and absolute

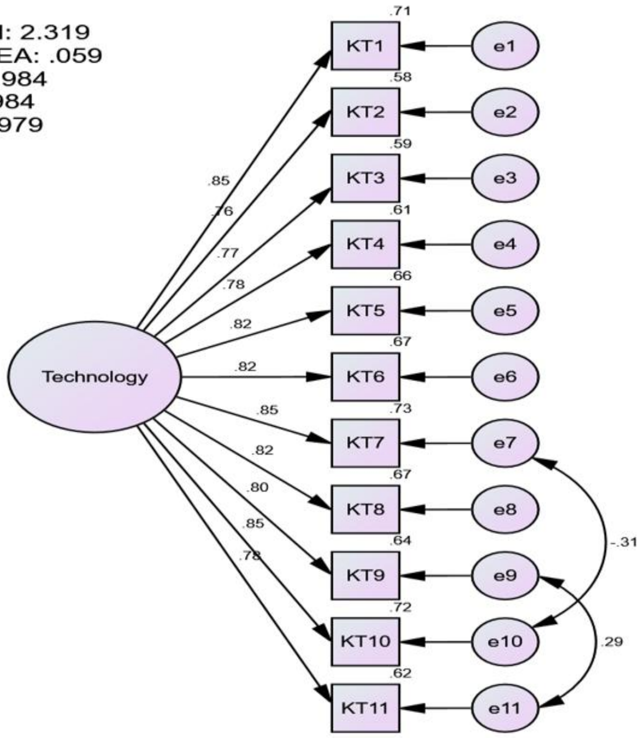

Figure 4. Modified first-order CFA model for technology career interest (Source: Authors' own elaboration, based on the CFA Results)

Table 6. Goodness-of-fit indices for the modified technology career interest CFA model

Category	Fit Index	Index Value	Research Finding
Parsimonious Fit	ChiSq/df	2.319	Met the required threshold
Absolute Fit	RMSEA	0.059	Met the required threshold
Comparative Fit	CFI	0.984	Met the required threshold
Incremental Fit	IFI	0.984	Met the required threshold
Tucker-Lewis Fit	TLI	0.979	Met the required threshold

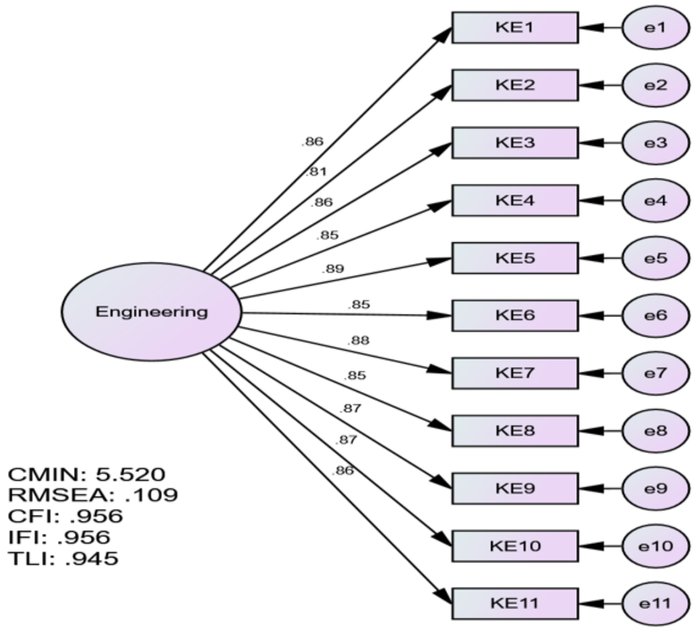

Figure 5. Initial first-order CFA model for engineering career interest (Source: Authors' own elaboration, based on the CFA Results)

Table 7. Goodness-of-fit indices for the initial engineering career interest CFA model

Category	Fit Index	Index Value	Research Finding
Parsimonious Fit	ChiSq/df	5.520	Did not meet the required threshold
Absolute Fit	RMSEA	0.109	Did not meet the required threshold
Comparative Fit	CFI	0.956	Met the required threshold
Incremental Fit	IFI	0.956	Met the required threshold
Tucker-Lewis Fit	TLI	0.945	Met the required threshold

fit. In addition, the comparative and incremental fit indices were strong, with CFI = 0.984, IFI = 0.984 and TLI = 0.979. These results indicate that the modified Technology Career Interest model provided a better fit to the empirical data and was therefore retained for subsequent reliability and validity analysis.

Figure 5 and **Table 7** present the initial first-order CFA model for Engineering Career Interest. The initial model showed acceptable comparative and incremental fit, as indicated by CFI = 0.956, IFI = 0.956 and TLI = 0.945. However, the ChiSq/df value of 5.520 and RMSEA value of 0.109 did not meet the recommended thresholds, suggesting that the initial model did not fully fit the empirical data. These results indicate that although the Engineering Career Interest items generally represented the construct, the overall model required further refinement. Therefore, model modification was conducted based on Modification Indices and theoretical justification to improve the goodness-of-fit of the Engineering Career Interest measurement model.

Figure 6 and **Table 8** present the modified first-order CFA model for Engineering Career Interest. After model modification, the goodness-of-fit indices improved and achieved the recommended thresholds. The ChiSq/df value decreased to 3.399, while the RMSEA value improved to 0.079, indicating acceptable parsimonious and absolute fit. The comparative and incremental fit indices also demonstrated strong model fit, with CFI = 0.979, IFI = 0.979 and TLI = 0.971. These findings indicate that the modified Engineering Career Interest model provided an acceptable fit to the empirical data and was retained for subsequent reliability and convergent validity assessment.

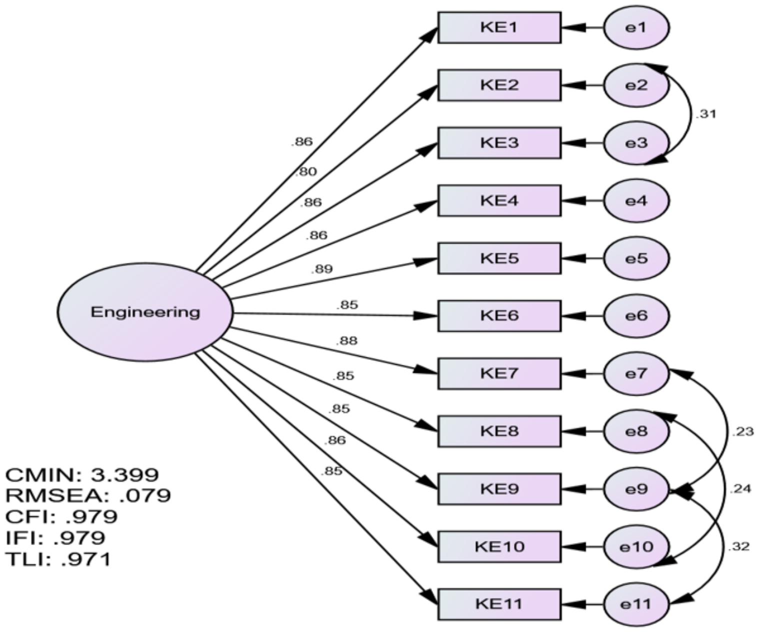

Figure 6. Modified first-order CFA model for engineering career interest (Source: Authors' own elaboration, based on the CFA Results)

Table 8. Goodness-of-fit indices for the modified engineering career interest CFA model

Category	Fit Index	Index Value	Research Finding
Parsimonious Fit	ChiSq/df	3.399	Met the required threshold
Absolute Fit	RMSEA	0.079	Met the required threshold
Comparative Fit	CFI	0.979	Met the required threshold
Incremental Fit	IFI	0.979	Met the required threshold
Tucker-Lewis Fit	TLI	0.971	Met the required threshold

Figure 7 and **Table 9** present the first-order CFA model for Mathematics Career Interest. The model demonstrated acceptable overall fit, with ChiSq/df = 3.873, CFI = 0.973, IFI = 0.973 and TLI = 0.966, all of which met the recommended thresholds. Although the RMSEA value of 0.087 was slightly above the recommended cut-off, it was considered marginally acceptable because the remaining fit indices showed strong comparative and incremental fit. Therefore, the Mathematics Career Interest model was retained without further modification. This decision was also made to avoid unnecessary model adjustment and to preserve the theoretical structure of the construct.

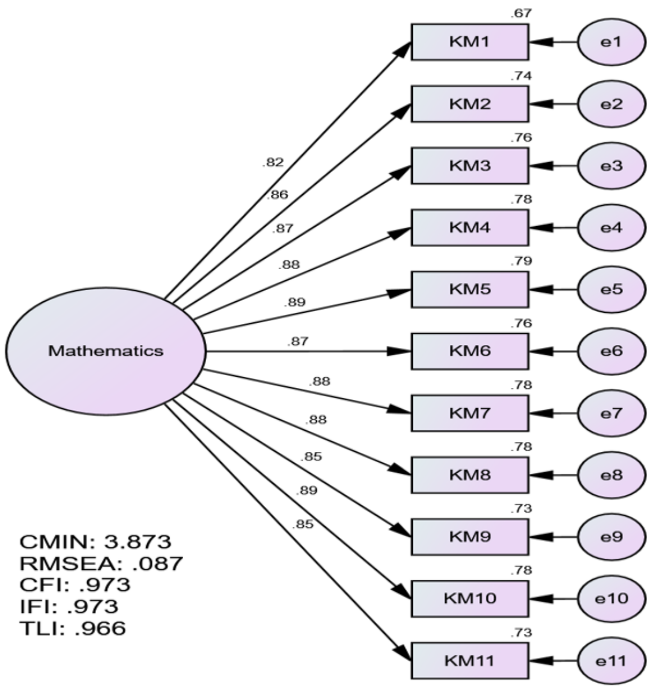

Figure 7. Initial first-order CFA model for mathematics career interest (Source: Authors' own elaboration, based on the CFA Results)

Table 9. Goodness-of-fit indices for the initial mathematics career interest CFA model

Category	Fit Index	Index Value	Research Finding
Parsimonious Fit	ChiSq/df	3.873	Met the required threshold
Absolute Fit	RMSEA	0.087	Marginally Acceptable
Comparative Fit	CFI	0.973	Met the required threshold
Incremental Fit	IFI	0.973	Met the required threshold
Tucker-Lewis Fit	TLI	0.966	Met the required threshold

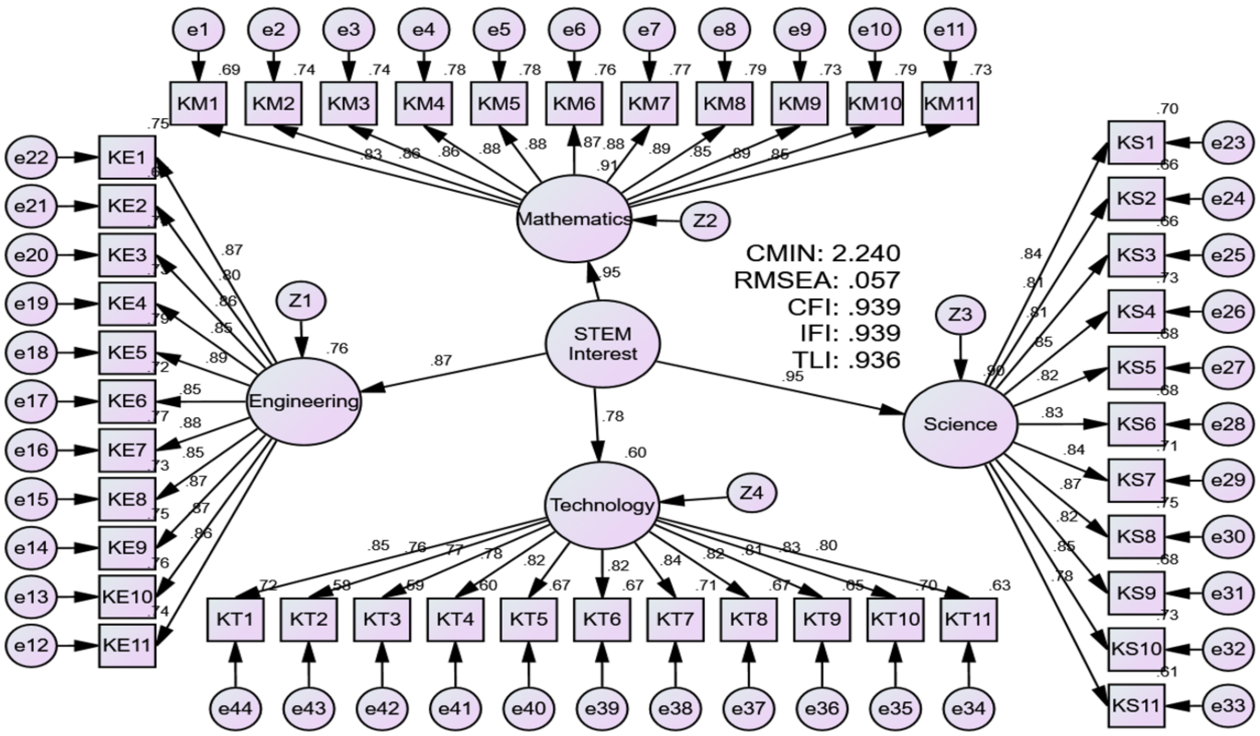

Figure 8. Second-order measurement model for STEM career interest (Source: Authors' own elaboration, based on the CFA Results)

Table 10. Reliability and convergent validity of STEM career interest dimensions

Construct	Number of Items	Factor Loading Range	Average Loading	Cronbach's Alpha	AVE	CR	Decision
Science	11	0.783–0.869	0.830	0.960	0.690	0.961	Accepted
Technology	11	0.764–0.847	0.809	0.954	0.654	0.954	Accepted
Engineering	11	0.804–0.887	0.858	0.968	0.737	0.969	Accepted
Mathematics	11	0.829–0.889	0.868	0.971	0.753	0.971	Accepted

Figure 8 presents the second-order measurement model for STEM Career Interest. The model was examined to determine whether the four first-order dimensions, namely Science Career Interest, Technology Career Interest, Engineering Career Interest and Mathematics Career Interest, could collectively represent a broader higher-order construct of STEM Career Interest. The second-order structure is appropriate because the four STEM domains are conceptually distinct, yet theoretically related as components of students' overall orientation toward STEM-related career pathways.

Table 10 presents the reliability and convergent validity results for the four dimensions of STEM Career Interest. The findings indicate that all dimensions achieved satisfactory standardised factor loadings. Science Career Interest recorded factor loadings ranging from 0.783 to 0.869, Technology Career Interest ranged from 0.764 to 0.847, Engineering Career Interest ranged from 0.804 to 0.887, and Mathematics Career Interest ranged from 0.829 to 0.889. The average factor loadings ranged from 0.809 to 0.868, indicating that the retained items adequately represented their respective latent constructs.

Table 11 summarises the first-order CFA model fit for the STEM Career Interest dimensions. The initial Science model was not fully acceptable due to ChiSq/df = 5.071 and RMSEA = 0.103. However, after modification, the model achieved acceptable fit with ChiSq/df = 3.229, RMSEA = 0.076, CFI = 0.978, IFI = 0.978 and TLI = 0.968. Similarly, the initial Engineering model did not fully meet the required fit criteria, with ChiSq/df = 5.520 and RMSEA = 0.109. After modification, the Engineering model achieved acceptable fit with ChiSq/df = 3.399, RMSEA = 0.079, CFI = 0.979, IFI = 0.979 and TLI = 0.971.

Table 11. Summary of first-order CFA model fit for STEM career interest dimensions

Dimension	Model	ChiSq/df	RMSEA	CFI	IFI	TLI	Decision
Science	Original	5.071	0.103	0.954	0.954	0.942	Not fully acceptable
Science	Modified	3.229	0.076	0.978	0.978	0.968	Accepted
Technology	Original	3.456	0.080	0.968	0.968	0.960	Marginal / acceptable
Technology	Modified	2.319	0.059	0.984	0.984	0.979	Accepted
Engineering	Original	5.520	0.109	0.956	0.956	0.945	Not fully acceptable
Engineering	Modified	3.399	0.079	0.979	0.979	0.971	Accepted
Mathematics	Final	3.873	0.087	0.973	0.973	0.966	Acceptable

Table 12. Model modification summary for STEM career interest dimension

Dimension	Correlated Error Terms	Justification
Science	e1–e5, e2–e9, e4–e9, e6–e8, e8–e10	Similar item wording and overlapping content context
Technology	e7–e10, e9–e11	Similar context related to technology use and technology-based career interest
Engineering	e2–e3, e7–e9, e8–e9, e8–e10, e9–e11	Similar meaning and overlapping engineering career content
Mathematics	None	No theoretically strong MI suggestion; model retained to avoid overfitting

For Technology Career Interest, the initial model showed marginal fit with ChiSq/df = 3.456 and RMSEA = 0.080, although the comparative and incremental indices were acceptable. After modification, the Technology model demonstrated stronger fit, with ChiSq/df = 2.319, RMSEA = 0.059, CFI = 0.984, IFI = 0.984 and TLI = 0.979. Meanwhile, the Mathematics model was retained as the final model, with ChiSq/df = 3.873, CFI = 0.973, IFI = 0.973 and TLI = 0.966. Although the RMSEA value of 0.087 was marginally above the recommended threshold, the overall pattern of fit indices indicated that the model remained acceptable.

Table 12 presents the model modification summary for the STEM Career Interest dimensions. Model modification was conducted only when supported by Modification Indices and theoretical justification. For Science Career Interest, correlated error terms were added between e1–e5, e2–e9, e4–e9, e6–e8 and e8–e10 due to similar item wording and overlapping content context. For Technology Career Interest, correlated error terms were added between e7–e10 and e9–e11 because the items shared similar content related to technology use and technology-based career interest. For Engineering Career Interest, correlated error terms were added between e2–e3, e7–e9, e8–e9, e8–e10 and e9–e11 because the items reflected closely related meanings and overlapping engineering career content.

No correlated error term was added to the Mathematics Career Interest model because no theoretically strong Modification Index was identified. This decision was made to preserve the theoretical structure of the model and to avoid unnecessary model modification. Overall, the modification process was applied cautiously and remained within the same latent construct, ensuring that the improvement in model fit did not compromise the conceptual validity of the STEM Career Interest measurement model.

DISCUSSION

The findings of this study provide empirical support for the four-dimensional measurement model of STEM Career Interest among secondary school students. The confirmation of Science Career Interest, Technology Career Interest, Engineering Career Interest and Mathematics Career Interest is consistent with Kier et al. (2014), who developed the STEM Career Interest Survey as an instrument grounded in Social Cognitive Career Theory and organised around four discipline-specific STEM career domains. This finding is also aligned with Malaysian STEM career interest research by Idris et al. (2023), which examined STEM interest among secondary school students in Malaysia and highlighted the relevance of science, technology, engineering and mathematics as specific domains of students' career orientation. Therefore, the present findings strengthen the interpretation of STEM Career Interest as a multidimensional construct rather than as a single general measure of interest.

The standardised factor loadings obtained in this study indicate that all items were suitable indicators of their respective latent constructs. Science Career Interest recorded factor loadings between 0.783 and 0.869, Technology Career Interest between 0.764 and 0.847, Engineering Career Interest between 0.804 and 0.887, and Mathematics Career Interest between 0.829 and 0.889. These values show that the observed items represented their intended STEM domains strongly and consistently. In CFA-based validation, strong factor loadings are important because they demonstrate that the observed indicators adequately reflect their underlying latent constructs, while weak loadings may indicate problematic item representation or construct instability (Hair Jr et al., 2019; Kline, 2016). This finding supports the suitability of the 44-item STEM-CIS structure in the Malaysian secondary school context.

The reliability results further confirmed that the STEM Career Interest measurement model achieved excellent internal consistency. Cronbach's alpha values ranged from 0.954 to 0.971, while Composite Reliability values ranged from 0.954 to 0.971. These values exceeded the recommended threshold of 0.70, indicating that the items within each dimension consistently measured the same underlying construct (Hair et al., 2019). Cheung et al. (2024) recommended that SEM-based studies report reliability and validity evidence using multiple criteria, including Composite Reliability and convergent validity, rather than relying on a single reliability indicator. Therefore, the high Cronbach's alpha and CR values in this study provide strong evidence that Science, Technology, Engineering and Mathematics Career Interest were measured reliably among secondary school students.

The AVE values also supported the convergent validity of all four STEM Career Interest dimensions. Science Career Interest recorded an AVE of 0.690, Technology Career Interest recorded 0.654, Engineering Career Interest recorded 0.737, and Mathematics Career Interest recorded 0.753. These values exceeded the recommended threshold of 0.50, indicating that each latent construct explained a sufficient proportion of variance in its observed indicators (Fornell & Locker, 1981). This evidence is important because convergent validity demonstrates that items within the same construct are meaningfully related and measure the same theoretical domain (Cheung et al., 2024). Hence, the findings confirm that the STEM-CIS dimensions used in this study achieved adequate convergent validity.

The model fit results further strengthened the validity of the STEM Career Interest measurement model. The modified CFA models for Science, Technology and Engineering achieved acceptable fit after theoretically justified modifications, while the Mathematics model was retained without modification due to acceptable overall fit and consistently high factor loadings. This model evaluation approach is appropriate because CFA should be assessed using multiple fit indices rather than relying on one fit statistic only (Kline, 2016). In the present study, the use of ChiSq/df, RMSEA, CFI, IFI and TLI enabled the measurement model to be evaluated through different categories of fit, including parsimonious, absolute and incremental fit. The uploaded CFA results also showed that modifications were conducted only for selected dimensions and were justified by item similarity and overlapping content.

The use of model modification in this study was methodologically defensible because correlated error terms were included only when supported by content-based and theoretical justification. Kline (2016) emphasised that CFA is a theory-driven technique, and any modification should be interpreted in relation to measurement theory rather than statistical improvement alone. In this study, correlated error terms were allowed only among items with similar wording, shared meaning or closely related content within the same STEM domain. Therefore, the modification process improved model fit while preserving the theoretical structure of the STEM Career Interest construct.

The decision to retain the Mathematics model without additional modification also reflects a cautious and theory-sensitive validation approach. Although the RMSEA value for Mathematics was slightly above the ideal cut-off, other fit indices such as CFI, IFI and TLI exceeded 0.90, indicating acceptable comparative and incremental fit. Since CFA model evaluation should be based on the overall pattern of fit evidence rather than a single index, the Mathematics model remained acceptable for interpretation (Kline, 2016). This decision also reduced the risk of overfitting, which may occur when excessive model modifications are made only to improve statistical fit.

The findings also support the use of both first-order and second-order CFA in validating STEM Career Interest. First-order CFA confirmed that Science, Technology, Engineering and Mathematics functioned as valid independent dimensions, while second-order CFA supported the interpretation of these four dimensions as components of a broader STEM Career Interest construct. Kier et al. (2014) reported that the STEM-CIS can function as both a general STEM career interest instrument and as four discipline-specific subscales. This is consistent with the present study, where STEM Career Interest was examined as a multidimensional construct consisting of related but distinct STEM domains. The present findings also contribute to the growing body of Malaysian STEM education research. Previous work by Idris et al. (2023) highlighted that STEM education in Malaysia continues to face challenges, including declining STEM participation and the difficulty of achieving the intended balance between science and non-science pathways.

From a practical perspective, the validated measurement model may help teachers, school counsellors and researchers identify students’ specific areas of STEM career interest. Students may not show equal interest across all STEM domains; for example, some may show stronger interest in technology or engineering, while others may demonstrate stronger interest in science or mathematics. Malaysian STEM research has emphasised that strengthening STEM participation requires attention not only to curriculum implementation, but also to students’ motivation, career awareness and perceived relevance of STEM pathways (Ministry of Education Malaysia, 2013). Therefore, a validated domain-specific STEM Career Interest model can support more targeted STEM exposure, counselling and intervention programmes.

Overall, the CFA findings indicate that the STEM Career Interest measurement model is valid, reliable and suitable for use among secondary school students. The strong factor loadings, high Cronbach’s alpha values, strong Composite Reliability and acceptable AVE values provide sufficient evidence that the four dimensions measured STEM Career Interest effectively. By validating this model, the present study contributes to STEM education research by providing psychometric evidence for the use of STEM-CIS in the Malaysian secondary school context. This contribution is important because a valid measurement model is necessary before STEM Career Interest can be examined in relation to broader psychological, educational and demographic factors.

RECOMMENDATIONS FOR FUTURE RESEARCH

The future research is required to validate the STEM Career Interest measurement model at different educational levels, states and school contexts in Malaysia. The present study focused on Form One students in Perak. Therefore, this research interested in the stability of the same four-dimensional structure among students at upper secondary level of education in different regions and different types of schools. This is also expected to provide further evidence to support the generalisability of the STEM Career Interest measurement model.

Future research should also explore the measurement invariance of STEM Career Interest across gender, locality and socio-economic status, as previous studies have shown that the STEM career choice and participation may be different by gender and educational background. Testing the measurement invariance would help us to see whether the STEM Career Interest model was indeed the same across different student groups. This is necessary to ensure that comparisons between STEM career interest of different demographics are valid. In addition, future research might consider a shorter version of the STEM Career Interest instrument.

Although the 44-item model is very reliable and convergent in this study, a shorter validated version would be more helpful to teachers, school counsellors and policymakers. Future research may also consider the relationship between STEM career interest and other psychological and educational variables including self-efficacy, STEM identity, parental support, teacher support and career exposure to better understand the factors influencing students' STEM career pathways.

CONCLUSION

In this study, the findings confirmed this STEM Career Interest measurement model for Malaysian secondary school students using first-order and second-order Confirmatory Factor Analysis. The result showed that Science Career Interest, Technology Career Interest, Engineering Career Interest, and Mathematics Career Interest are valid aspects of the STEM Career Interest model. All the items had good factor loadings, and the reliability and convergent validity results showed that the instrument had good Cronbach's alpha, Composite Reliability, and AVE values. The model fit results also supported the satisfactory fit to the measurement model.

The modified models of Science, Technology and Engineering fit well and the mathematics model was retained without further modification. The second-order CFA also confirmed the higher-order nature of STEM Career Interest as a higher-order construct with four related but distinct STEM domains. These results demonstrate that the STEM Career Interest measurement model is valid and reliable for measuring students' domain-specific interest in STEM-related career pathways.

This research contributes to the STEM education field by providing psychometric evidence for the use of STEM-CIS in Malaysian lower secondary school. While previous research uses STEM career interest as an outcome variable, this study fills a methodological gap in the field, by confirming the dimensionality, reliability, convergent validity and higher-order structure of STEM Career Interest. It is clear that STEM career interest should not be viewed only as a general definition, but rather as a multidimensional construct which includes science, technology, engineering and mathematics career interest.

This study fills this gap, and thus will lay the foundation for future STEM education research in Malaysia. The validated model can help researchers, teachers, school counsellors and policymakers to identify students' specific STEM career interest profiles. It could also be valuable in planning more targeted STEM guidance programmes, career awareness activities and educational interventions that are customized to students' diverse interests under STEM domains. This study therefore contributes not only to measurement validation but also to the overall achievement in STEM participation and career readiness among Malaysian secondary school students.

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