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Exploratory Factor Analysis of Stem Self-Efficacy in The Context of Malaysian Stem Subjects' High Performers

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Abstract

STEM education has been a topic of interest for many years, among those are the issue of decreasing number of students showing interest in continuing the academic pathway in STEM. It is also a global issue where among who refuse to take up STEM pathways are those who are high performer students. Among the factors that lead to this situation is low STEM self-efficacy. This study aims to validate the measurement model for the STEM self-efficacy construct in the context of Malaysian STEM subjects' high performers. Generally, the Exploratory Factor Analysis (EFA) is needed to uncover the suitable items to be used in research instruments. This study adopted a purposive research sampling with data collected from the Law and TESL fundamentals students enrolled in a public university in Malaysia. Items with a 10-interval scale were used. Using the Principal Component extraction method with Varimax Rotation, the researchers performed the EFA procedure on construct elements using SPSS software. Bartlett's Test of Sphericity and the Kaiser-Meyer-Olkin (KMO) sampling adequacy were also performed. Cronbach's alpha was used to test the reliability of the retained items. All the 15 items for STEM self-efficacy are retained. Based on the factor analysis, this study finalized the instrument of 15 STEM self-efficacy items; yielding 3 dimensions, i.e., science self-efficacy (7 items), engineering self-efficacy (5 items), and mathematics self-efficacy (3 items). This study explained in detail the procedures for carrying out the STEM self-efficacy construct. The researcher hopes that this study adds new insight into STEM self-efficacy, particularly among the high STEM achievers.

Keywords: STEM, Exploratory Factor Analysis, Self-Efficacy, STEM Subject High Achievers

Introduction

Science education is of the utmost importance to the human race Godek (2004); Kola (2013); Singh (2022), and it has been recognized for a considerable amount of time that there is a problem with an inadequate number of students enrolling in the Science Technology Engineering and Mathematics (STEM)-related courses stream (Denissen et al., 2007; Shahali et al., 2019; Sze et al., 2022).

Several longitudinal studies were carried out to study the issue. The National Academies of the United States of America came out with a report entitled 'Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future' (Rising above the, 2007). The Relevance of Science Education (ROSE) project, which included many European countries, began in 2004 in Norway as a cooperative research project with extensive international involvement (Sjoberg and Schreiner, 2005). Its main focus was on the emotional side of how young people learn about science and technology. As part of its Targeted Initiative on Science and Mathematics Education, the UK's Economic and Social Research Council funded a five-year longitudinal study called Science and Career Aspiration (ASPIRES) in the United Kingdom (DeWitt et al., 2013).

In 1962, the Malaysian Educational Planning and Research Division set up a group to plan the direction of human resource development as part of Malaysia's educational evolution. Based on this committee's idea, the Higher Educational Planning Board made it so that 60% of students would be in the arts and 40% would be in science in 1969 (Phang et al., 2014). Unfortunately, the strategy did not work out as planned (Kaur et al., 2020; Shahali et al., 2018).

The prevailing circumstances in Malaysia and numerous other countries indicate the prevailing apathy towards STEM areas among aspiring pupils. One of the characteristics that has been examined to determine why students choose not to pursue STEM subjects or occupations is their lack of confidence in their ability to succeed in STEM (Dorfman and Fortus, 2019).

Deciding on an academic pathway is a complicated process. Studies show that many internal factors lead to fewer students choosing to be in the STEM field, academically or career-wise (Arif et al., 2019; Giang and Nhung, 2022). The internal factors include cognitive-based reasons, such as self-efficacy (van Aalderen-Smeets et al., 2019; van de Hurk et al., 2019).

Studying the effect of STEM self-efficacy on course selection as well as the STEM attrition issue is crucial for several reasons. Understanding how students perceive their ability to succeed in STEM subjects informs educational planners about the factors influencing students' choices. This insight can help in designing courses and programs that cater to student's needs and interests. Self-efficacy beliefs significantly influence academic performance and persistence in STEM fields. By studying how self-efficacy relates to course selection, educators can identify strategies to support students with lower self-efficacy, potentially improving retention rates and academic success in STEM disciplines.

Course selection in STEM fields often shapes career pathways. Researching the impact of self-efficacy on course selection can provide insights into the factors influencing students' decisions to pursue STEM-related courses. This understanding is essential for promoting diversity and inclusion in STEM fields by addressing barriers that may affect student psychology.

Knowledge of how self-efficacy influences course selection can inform pedagogical approaches. Educators can tailor teaching methods and support mechanisms to enhance students' self-efficacy, thereby increasing engagement and learning outcomes in STEM

courses. Findings regarding the relationship between STEM self-efficacy and course selection can inform educational policies aimed at promoting STEM education and workforce development. Policy initiatives can target interventions to bolster students' self-efficacy in STEM, fostering a more robust pipeline of skilled professionals in these fields.
Overall, studying the effect of STEM self-efficacy on course selection is vital for creating supportive learning environments, promoting diversity in STEM, and addressing challenges related to student engagement and success in these critical fields.

Literature Review
In the process of selecting an academic path, individual characteristics play a significant role (Mullet et al., 2017). One of the psychological characteristics is a sense of self-efficacy. There has been extensive research conducted on the impact that self-efficacy has on academic trajectories, particularly with regard to issues of attrition in STEM fields (Ghaleb et al., 2015; Gaylor and Nicol, 2016; Wu et al., 2020; Zimmerman, 2000). In order for students to be successful in STEM education, it is essential for them to have the appropriate attitudes towards the fields of science, technology, engineering, and mathematics (Ugras, 2018).
In general, self-efficacy is a cognitive concept that refers to an individual's views about their ability to successfully carry out the tasks that are necessary to attain their goals (Bandura, 1997; Hutchison et al., 2006; Mamaril et al., 2016). The term "academic self-efficacy" refers to the degree to which students have faith in their capacity to undertake academic responsibilities, such as preparing for examinations and writing term papers (Zajacova et al., 2005). Self-efficacy beliefs can have either a positive or negative impact on an individual's behaviour, depending on how well they are able to perform a specific task in proportion to someone else's abilities. For example, a person who has a high level of self-efficacy would be more inclined to engage in activities, put in more effort, and persevere for a longer period of time when confronted with failure, obstacles, and difficulties than a person who has a low level of self-efficacy (Lazarides et al., 2018; Renninger & Hidi, 2019).
Researchers have found that feelings of self-efficacy have an effect on students' attitudes, which in turn affects the choices that they make. Self-efficacy was described by Ekmekci et al. (2019) as being among the most notable psychological constructs that impact students' academic and career decisions, which helps to create high expectations toward students' future endeavors. The conceptual framework of social cognition theory served as the intellectual foundation for this description. There is a correlation between students' levels of self-efficacy and the degree to which they consider a specific academic task to be fascinating or beneficial (Wigfield & Eccles, 2000). It has also been found through empirical study that students who seek degrees relevant to STEM fields have a strong correlation with their high levels of self-efficacy in STEM topics (Shahali et al., 2019; Rivera & Li, 2020). As a result of their conviction that a STEM education or career can assist them in accomplishing such life goals, these students will make the decision to enroll in STEM-related classes and seek careers linked to STEM fields.
This article is to report the result of the EFA analysis on the STEM self-efficacy scale which is part of a larger study that focuses on the issues of Malaysian high performers in STEM subjects but eventually leaving the STEM stream.

Exploratory Factor Analysis
Typically, in social science studies, there are two main classes of factor analysis: Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). Before doing the subsequent

CFA, the EFA is conducted first (Afthanorhan et al., 2014). In general, EFA is empirical. EFA has been one of the statistical techniques that is used the most frequently, particularly in social science research. Research suggests that the EFA technique produces more precise results when multiple measurable variables that are either endogenous or exogenous constructs in the analysis are used to represent each common factor (MacCallum et al., 1999; Velicer and Fava, 1998). In addition, EFA outlines the fundamental relationship among the studied variables and cannot be measured directly, but is represented as a group of items (Hair et al., 2014). According to Nayak and Sahoo (2015) , EFA is used when the number of factors included in a set of variables is unclear.

As the name implies, EFA is exploratory, and researchers have no assumptions regarding the quantity or kind of variables. That is, it enables the researchers to investigate the key dimensions in order to develop a theory or model from a sizable collection of latent constructs, frequently represented by a set of items. Principal component analysis (PCA), which is utilized for data reduction in EFA, does not distinguish between common and unique variance (Bentler and Kano, 1990). As advised by Hair et al (2011), in the EFA technique, the value is suppressed at the threshold of 0.60 or higher once the EFA procedure is implemented. It is suggested that the high factor loading is a crucial signal. Moreover, EFA proposes the factor loading into the same component, in addition to minimizing the number of variables used in this investigation. Indicators included in the same component demonstrate that this outer loading aims to represent the measurement model. This component will be used in structural equation modelling after the researchers complete the EFA technique (SEM).

Methodology

In order to provide a valid and reliable measurement scale for the STEM self-efficacy construct, specifically within the setting of STEM high achievers (individuals who have demonstrated exceptional performance in pure sciences and mathematical subjects), this study employed a correlational research design**.** How a researcher designs, structures, and implements a study can affect the research findings and is an important consideration regarding bias (Bloomfield and Fisher, 2019). Purposive sampling was selected as the sampling technique. Mahmud (2011) asserted it is the appropriate sampling technique if the researcher sets certain criteria for the potential respondent. The study participants comprised law and TESL fundamentals students enrolled in a public university located in Selangor, Malaysia. They received a minimum of one A and three B in the following STEM-related subjects: Additional Mathematics, Biology, Chemistry, and Physics in SPM, which is utilized as a requirement for students to apply for higher study. Despite having excellent results in these subjects, they chose Fundamental in TESL or Fundamental in Law.

The online questionnaire link was disseminated through several channels accessible to potential respondents. The procedures for selecting respondents were explicitly outlined in order to mitigate any potential confusion among students aspiring to participate as respondents. Within the designated timeframe, a total of 111 students responded to the online questionnaire. Data were collected through Google form and analyzed using Exploratory Factor Analysis (EFA) to establish the rotated component analysis used for significant items in the model. To determine the suitable STEM self-efficacy measures among high performers in Malaysia, the researchers developed a structured questionnaire that comprised 15 items, which were measured using a 10-point interval scale, from “1 = Strongly Disagree” to“10 = Strongly Agree”. The STEM self-efficacy scale is divided into three parts; the science self-efficacy was adopted from Baldwin et al (1999) and National Research Council

(2012); the mathematics self-efficacy was adopted from Kranzler & Pajares (1997) while the Engineering self-efficacy was adopted from (Sze et al., 2022)

Results
Through the process of calculating the coefficient alpha, one is able to evaluate the reliability of a scale. Consequently, the traditional Cronbach's alpha method was utilised in order to evaluate the reliability of the items that were included in the study. Furthermore, according to Sekaran and Bougie (2010), a more favourable coefficient alpha is one that is greater than 0.70. This is based on the suggestion made by Nunnally (1978). Cronbach's alpha is a constant coefficient, according to Sekaran and Bougie (2010), which indicates that the associations between the item sets are proportionally connected with one another. On top of that, he believes that a model is deemed to be weak if it has a dependability value that is lower than 0.70. Furthermore, according to Table xx, the 15 items that make up the questionnaire have a Cronbach's alpha value of 0.914, which demonstrates that the STEM self-efficacy construct components are suitable and reliable for the purpose of measuring the answer.

Kaiser_Meyer-Olkin (KMO) and Bartlett's Test of Sphericity
The researchers employed exploratory factor analysis (EFA) utilising principal component analysis with the varimax rotation technique on a sample of 100 datasets. The purpose of this analysis was to assess and refine the scale items, as well as to identify the items that should be grouped together inside the same components. Hair et al (2008) state that a Kaiser-Meyer-Olkin (KMO) value exceeding 0.50 should be employed to ensure the purity of the measurement items. Nevertheless, this study used factor loadings above 0.60, so that only the remaining high factor loading can be processed for the following step. The KMO value of 0.899 (Table xx) is exceptional in this study, as it exceeds the recommended threshold of 0.6. Furthermore, for factor analysis to be considered acceptable, the value of Bartlett's Test of Sphericity must be below 0.05 (p-value < 0.05). The significant value of Bartlett's Test for the current study is < 0.001, which satisfies the predetermined significance level of less than 0.05. (Awang, 2012; Houque et al, 2018). Both Bartlett's Test of Sphericity is significant (p-value < 0.05) and the sampling adequacy by Kaiser–Meyer–Olkin (KMO) is excellent since it exceeded the required value of 0.6. According to Awang (2015); Yayaya et al (2018), the available data are sufficient to proceed with the data reduction phase in EFA. The procedure of extracting the total variance explained involves reducing the number of components to a reasonable level prior to conducting additional analysis. According to Awang (2015), throughout this procedure, components that possess eigenvalues greater than 1.0 are separated into distinct components. The results indicated that the EFA procedure yielded three distinct components, as determined by an Eigenvalue over 1.0. The eigenvalues ranged between 8.370 and 1.385. Meanwhile, the variance explained for component 1 is 55.797%, for component 2 is 15.525%, and for component 3 is 9.232. This construct's measurement yields a total explained variance of 80.555%. The total variance explained is deemed acceptable as it exceeds the prescribed minimum threshold of 60% (Awang et al., 2017). This indicates that the items are grouped into three dimensions with a total explained variance of 80.555%, which would be considered for further analysis.

Scree Plot
In order to identify the total number of components that comprise the STEM Self-Efficacy construct, the Exploratory Factor Analysis (EFA) was utilised for the purpose of conducting

data analysis. According to the screen plot, which is depicted in Figure 1, three factors have been discovered. Additionally, three factors have been identified based on the initial eigenvalues and the total variance explained.

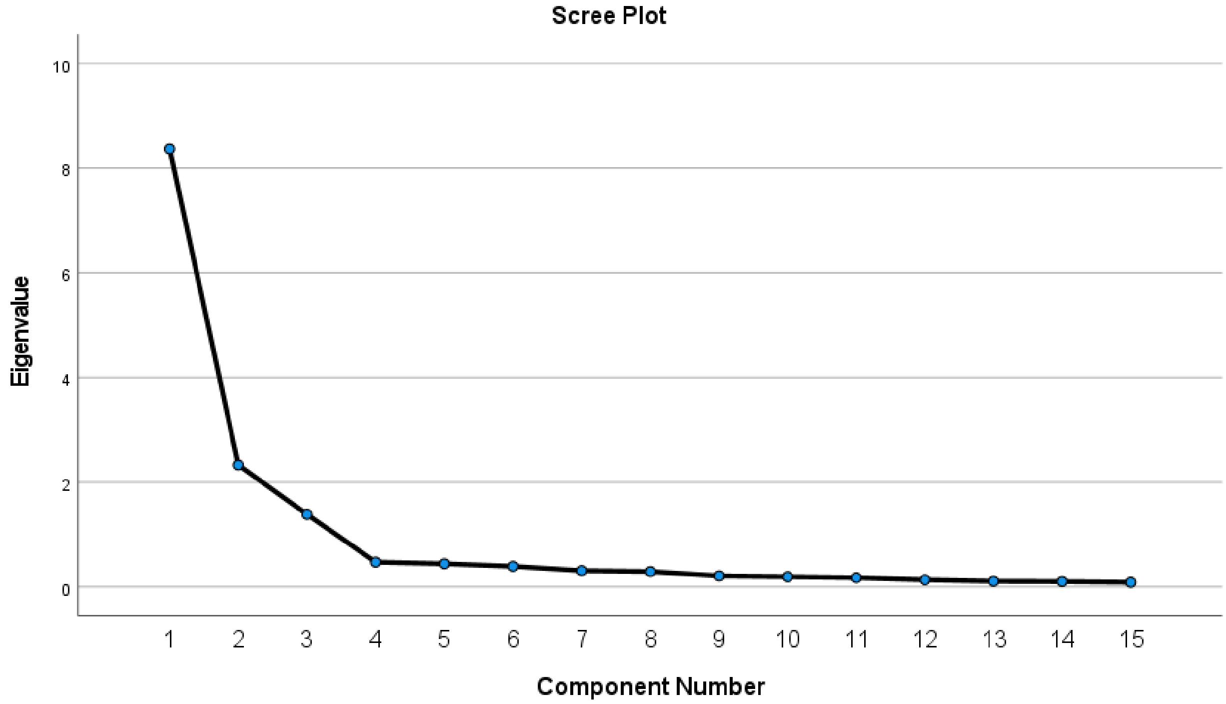

Figure 1. Scree plot for STEM self-efficacy construct

Component Matrix
In accordance with Awang (2012), the rotated component matrix was investigated, and for the purpose of further investigation, those items that had a factor loading that was greater than 0.6 were carried forward.
Table 1 displays the three dimensions or components that were identified, together with their corresponding items, as a consequence of the exploratory factor analysis (EFA) approach. In order to be kept, each item must have a factor loading greater than 0.6, as this reflects the effectiveness of the items in assessing the specific construct (Baistamam et al.,2022; Yahaya et al., 2018; Awang, 2015). As a result, Table 2 shows all 15 retained items, which will be considered for further analysis under the three dimensions of the Financial Literacy construct.

Table 1
Rotated Component Matrix of STEM Self-efficacy Construct

Item	Item Statement	Comp 1	Comp 2	Comp 3
1.	Analyse and interpret scientific data	.901		
2.	Ask questions about a scientific phenomenon	.858		
3.	Plan a scientific investigation	.855		
4.	Explain about a scientific phenomenon	.822		
5.	Find evidence that helps you to solve a scientific problem	.803		
6.	Successfully carrying out an experiment	.767		
7.	Can do well in sciences subjects	.674		
8.	Fix malfunction appliances		.880	

9.	Can complete the tasks that are related to handling of machines	.853		
10.	Can carry out task that are related to creativity and innovation	.853		
11.	Invent new product	.812		
12	Can be successful in the field of engineering	.802		
13.	Can use mathematics and computational thinking			.879
14.	Can use mathematical concepts that you learnt in your daily life			.828
15.	Can obtain, evaluate, and communicate about mathematical information			.822

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Table 2
Final Items for STEM Self-efficacy Construct

Item	Sub-Construct	Item Label	Item Statement	Comp 1	Comp 2	Comp 3
1.	Science self-efficacy	SSE1	Analyse and interpret scientific data	.901		
2.		SSE2	Ask questions about a scientific phenomenon	.858		
3.		SSE3	Plan a scientific investigation	.855		
4.		SSE4	Explain about a scientific phenomenon	.822		
5.		SSE5	Find evidence that helps you to solve a scientific problem	.803		
6.		SSE6	Successfully carrying out an experiment	.767		
7.		SSE7	Can do well in sciences subjects	.674		
8.	Engineering self-efficacy	ESE1	Fix malfunction appliances		.880	
9.		ESE2	Can complete the tasks that are related to handling of machines		.853	
10.		ESE3	Can carry out task that are related to creativity and innovation		.853	
11.		ESE4	Invent new product		.812	
12		ESE5	Can be successful in the field of engineering		.802	
13.	Mathematic self-efficacy	MSE1	Can use mathematics and computational thinking			.879
14.		MSE2	Can use mathematical concepts that you learnt in your daily life			.828
15.		MSE3	Can obtain, evaluate, and communicate about mathematical information			.822

	Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 5 iterations

Subsequently, the latent variables for each variable were formulated by the researchers, drawing upon the data presented in the EFA report. The present study examines STEM self-efficacy as a second-order concept, which is assessed through three distinct components: science self-efficacy, mathematical self-efficacy, and engineering self-efficacy. Finally, the researchers computed Cronbach's alpha using the internal reliability statistics test as presented in Table 3. The internal consistency reliability of the selected items in measuring the construct was assessed using Cronbach's alpha. The value of Cronbach's alpha should be greater than 0.7 for the items to achieve Internal Reliability (Awang, 2012).

Table 3
Internal Reliability for STEM self-efficacy construct

Component	Rename components	N of Items	Cronbach's Alpha
1	Science self-efficacy	7	.950
2	Engineering self-efficacy	5	.926
3	Mathematic self-efficacy	3	.926

Conclusion

This study makes a valuable contribution to the assessment of STEM self-efficacy, specifically focusing on high-achieving STEM students at a university in Malaysia. The EFA results of this study produced a structure that extracts three dimensions of the STEM self-efficacy construct, which are science self-efficacy, mathematics self-efficacy, and engineering self-efficacy. These dimensions can be measured using the 15 items developed in this study. This is because all of the reliability measures for the three dimensions showed a high Cronbach's alpha value, hence meeting Bartlett's Test achievements (significant), acceptable KMO values (>0.6), and factor loadings exceeding the minimum threshold of 0.6. This reflects that the items are applicable in this study.

This work contributes a significant survey instrument to the existing body of literature, which will facilitate the measurement of the dimensions of STEM self-efficacy. In light of the absence of a comprehensive definition and dimension for STEM self-efficacy, this study aims to investigate and assess the dependability of the STEM self-efficacy construct among STEM students in Malaysia, with a specific focus on high-achieving individuals in STEM courses. Therefore, employing the ultimate proven iteration of this dimension will prove advantageous for subsequent investigations. The implications of this study have the potential to inform future research on the structural model, hence offering valuable insights for applied researchers in the field of STEM education research.

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