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Students' Self-Regulated Learning in Physics: Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA)

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ABSTRACT

This study aims to develop and validate an instrument that measures students' self-regulated learning in Physics. The pilot study involved 400 randomly selected Form 4 students taking Physics. Exploratory Factor Analysis (EFA) was conducted to assess the suitability of the measurement items and to identify the construct dimensions. Three main components were identified through the EFA procedure, namely self-motivation (DP), metacognitive planning (PM), and metacognitive monitoring (PK). The field study involved 435 Form 4 students taking Physics from daily secondary schools. The study population consisted of Form 4 students from daily secondary schools across Peninsular Malaysia. The sample was selected using stratified random sampling and simple random sampling from four states: Perak, Kedah, Negeri Sembilan, and Kelantan. Data from the field study were used to confirm the validity and reliability of the instrument through the Confirmatory Factor Analysis (CFA) procedure. CFA results indicated that the developed instrument is valid and reliable for measuring students' self-regulated learning. Once the measurement model was confirmed through CFA, the researchers structured these constructs into a structural model and estimated the necessary parameters using the Structural Equation Modelling (SEM) procedure. This study makes a significant contribution by producing a valid and reliable instrument for measuring self-regulated learning among Form 4 Physics students. This instrument can be used in future research to enhance the understanding of factors influencing students' self-regulated learning in the context of Physics education.

1. Introduction

Self-regulated learning is a process where students actively control and manage their own learning. In the current educational context, this skill is becoming increasingly important as it encourages students to be more independent and responsible for their learning [1]. According to Zimmerman [2], self-regulated learning involves elements such as self-motivation, metacognitive planning, and monitoring of the learning process. This indicates that effective regulation can enhance academic achievement and develop more competitive students.

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Numerous studies have shown a positive relationship between self-regulated learning (SRL) and academic achievement at various levels of education [3-11]. By understanding how students regulate their own learning, we can gain valuable insights into the factors contributing to high achievement. This provides guidance for educators and institutions to improve teaching methodologies. Additionally, students who possess self-regulated learning skills are more likely to adapt to academic challenges, develop effective strategies, and achieve their learning goals [12]. Understanding the role of self-regulated learning in academic success is a crucial step for educators aiming to enhance learning effectiveness and help students reach their full potential.

The landscape of physics education in Malaysia has undergone significant transformation in recent years. With an emphasis on active and innovative learning approaches, physics teaching now focuses more on direct student engagement [13]. The curriculum is designed to develop a deep understanding of concepts, but the challenges faced by students in comprehending this subject remain an issue that needs to be addressed [14]. Therefore, self-regulated learning approaches are seen as a potential strategy to enhance achievement in this field.

In Malaysia, students face various challenges in the learning process, including factors such as socioeconomic background and differing teaching approaches [15]. Understanding self-regulated learning among secondary school students is crucial to comprehending how they interact with their learning processes. By focusing on self-motivation, metacognitive planning, and metacognitive monitoring, this study aims to validate the instrument used to measure constructs related to self-regulated learning elements within the context of physics education in Malaysia. This article includes discussions on the literature review, methodology, results of EFA and CFA analyses, as well as conclusions and recommendations for future research

2. Literature Review

Self-regulated learning (SLR) has been identified as an important approach in the educational context aimed at enhancing students' academic achievement. Self-regulated learning is a process where students actively control and manage their own learning [16]. Based on the theories and models of SLR developed by Pintrich [17] and Zimmerman [2], the importance of students planning, monitoring, and evaluating their own learning has been emphasized. According to Zimmerman [2], this regulation involves three main components: self-motivation, metacognitive regulation, and motivational regulation. Self-regulated learning not only enhances students' ability to be independent but also encourages them to take more responsibility for their own learning process. Previous studies have shown that students who practice SLR strategies tend to achieve better academic performance and have higher motivation compared to those who do not adopt these strategies [16,18].

Various instruments have been developed to measure self-regulated learning. In the study of self-regulated learning, there are gaps related to the validity and reliability of the instruments used [19]. Many instruments do not cover the important dimensions of self-regulated learning and lack empirical validation of the models used [20]. This can result in inaccurate outcomes and a lack of deep understanding of the factors influencing the effectiveness of self-regulated learning. Therefore, it is important to use analytical techniques that can identify and correct these issues. Among the frequently used instruments are the Self-Regulated Learning Questionnaire (SRL-Q) [3,21] and the Motivated Strategies for Learning Questionnaire (MSLQ) [22,23]. Research by Pintrich *et al.*,[24] has shown that these instruments can provide deep insights into the strategies students use to regulate their learning.

In this study, researchers chose to use instruments measuring three main sub-constructs: self-motivation, metacognitive planning, and metacognitive monitoring [2,25,26]. This selection is based on the importance of each sub-construct in determining the effectiveness of self-regulated learning. Self-motivation refers to students' drive to achieve their learning goals, while metacognitive planning involves the strategies used to plan and organize learning. Metacognitive monitoring refers to students' ability to assess and control their own learning processes. Selecting appropriate instruments is crucial as they are specifically designed for students studying physics, ensuring relevance and accuracy in measuring their self-regulated learning.

From this literature review, it can be concluded that self-regulated learning is a crucial element in education that requires deeper investigation. Choosing the right instruments and focusing on specific sub-constructs will provide clearer insights into this process, thereby helping in designing more effective teaching strategies [27]. The suitability of the instruments to the context of physics ensures that the study's results are relevant and beneficial for students' learning development.

To address this gap, EFA and CFA are essential steps to be taken. EFA is used to identify the underlying factor structure and assess the suitability of measurement items, while CFA is employed to validate the developed model and ensure the instrument's validity and reliability [28][29]. By applying both analyses, researchers can produce more valid and reliable instruments for measuring self-regulated learning, thus providing a deeper understanding of the factors influencing students' learning processes.

Therefore, researchers conducted this study to validate the self-regulated learning questionnaire instrument based on the perceptions of daily secondary school students in Malaysia, focusing on self-motivation, metacognitive planning, and metacognitive monitoring. Consequently, this study has the potential to help students develop the self-regulated learning strategies needed to achieve success [5,21,30].

2. Methodology

2.1 Research Design

The design of this study is a survey, utilizing a quantitative approach involving Form Four physics students from daily secondary schools in the states of Perak, Kedah, Negeri Sembilan, and Kelantan as respondents. Through the survey method, researchers can effectively identify problems and issues in education related to perceptions, beliefs, behaviors, and demographic characteristics of the respondents [31]. Additionally, data can be collected rapidly given the large number of respondents involved [32].

2.2 Population and Sample

The population of this study consists of Form Four students in daily secondary schools taking the Physics subject in Peninsular Malaysia. Data was collected in two phases: a pilot study and a field study. In the pilot phase, the sample involved 400 Form Four students from daily secondary schools across Peninsular Malaysia. In the field study phase, 435 Form Four students from daily secondary schools were selected from the states of Kedah, Kelantan, Negeri Sembilan, and Perak. The sample selection was carried out using stratified random sampling and simple random sampling methods. The researchers conducted a pilot study to pre-test the questionnaire instrument to ensure that the items measured could be used during the field study [33].

To conduct EFA and CFA, the minimum sample size recommended is 100 participants for the pilot study and between 300 to 500 respondents for the field study, as a requirement for conducting SEM

(Structural Equation Modelling). In this study, the construct measurement model was validated using CFA. For conducting EFA and CFA, the recommended minimum sample size is 100 participants for the pilot study, while for the field study, between 300 and 500 respondents are suggested as a requirement for conducting CFA and SEM [28,29]. In this study, the construct measurement model was confirmed using CFA.

2.3 Research Instruments

In the context of this study, a questionnaire survey was chosen to assess students' perceptions of self-regulated learning. The questionnaire consists of three sub-constructs: self-motivation, metacognitive planning, and metacognitive monitoring, containing a total of 20 items. These items were adapted from Dowson and McInerney [25] and Velayutham *et al.*, [26]. A 1 to 7 scale was used as an indicator for respondent feedback, with scale 1 labelled as "strongly disagree" and scale 7 as "strongly agree." The distribution of questionnaire items for each sub-construct is shown in Table 1.

Table 1
Distribution of questionnaire items and tests

Construct	Sub-Construct	Number of Items	Time to Complete	Source
Self-Regulated Learning	Self-Motivation	8	25 minit	[25][26]
	Metacognitive Planning	3		
	Metacognitive Monitoring	9		

3. Finding

3.1 Finding for the Pilot study

Before conducting the field study, a pilot study was carried out to assess the instruments for content validity, face validity, and construct validity. Six experts in the field of physics education were selected to validate these instruments. Additionally, ten students with similar criteria to the respondents were chosen to validate the instruments for face validity. After the validation process, the researchers made modifications based on the comments and suggestions provided by the experts and students [34].

This study conducted Exploratory Factor Analysis (EFA) to explore the usability of the modified items in measuring the construct of self-regulated learning. Subsequently, Confirmatory Factor Analysis (CFA) was performed to validate the measurement model of latent constructs concerning construct validity, convergent validity, discriminant validity, and composite reliability [29,35].

3.2 Reliability Analysis

The reliability scale was determined based on the calculation of the Alpha coefficient. The Cronbach's Alpha value is a reliability coefficient that reflects the extent to which the items used are related to each other in measuring the same construct [36]. An Alpha Cronbach value of around 0.80 and above indicates high reliability. Conversely, an Alpha Cronbach value of less than 0.60 is considered weak. However, if the Alpha Cronbach value is between 0.60 and 0.70, it can be considered sufficient to accept the reliability of the items [37].

Table 2 shows the reliability analysis for the self-regulated learning construct. The Cronbach's Alpha value for the self-motivation sub-construct is 0.932. For the metacognitive planning sub-construct, the Cronbach's Alpha reading is 0.827. Lastly, the Cronbach's Alpha value for the metacognitive monitoring sub-construct is 0.925. Overall, the Cronbach's Alpha value is 0.941. Thus, the obtained Cronbach's Alpha values indicate that all three sub-constructs of self-regulated learning are acceptable and reliable for measuring the respondents' perceptions during the field study.

Table 2
Cronbach's Alpha values for each sub-construct of self-regulated learning measured after EFA

Sub-Construct	Number of Items	*Alpha Cronbach*
Self-Motivation	8	0.932
Metacognitive Planning	3	0.827
Metacognitive Monitoring	9	0.925
Total	20	0.941

3.3 Exploratory Factor Analysis (EFA)

This pilot study was analyzed using the EFA procedure with IBM-SPSS software version 25.0. The extraction method used was Principal Component Analysis (PCA), while the rotation method applied was Varimax (Variation Maximization). The EFA produced a Kaiser-Meyer-Olkin (KMO) value of 0.934, as shown in Table 3. This KMO value reflects sampling adequacy that meets the minimum requirement of 0.6 [38]. The results in Table 3 also show a significant value for Bartlett's Test of Sphericity, with a p-value of less than 0.05.

Table 3
Kaiser-Meyer-Olkin (KMO) and Bartlett's Test for the self-regulated learning construct

Kaiser-Meyer-Olkin	Measure of Sampling Adequacy	.934
Bartlett's Test of Sphericity	Approx. Chi-Square	5980.698
	df	210
	Sig.	<.001

Table 4 presents the results for the total variance explained for the self-regulated learning construct. Three components have eigenvalues exceeding 1. These three factors collectively account for 65.99% of the total variance, surpassing the 60% threshold. Specifically, based on the extraction sums of squared loadings, Factor 1 contributes 46.85% of the variance, Factor 2 contributes 12.03%, and Factor 3 contributes 7.12%. These results indicate that the number of components and items are appropriate for field study implementation.

Table 4
Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.838	46.847	46.847	9.838	46.847	46.847
2	2.526	12.029	58.876	2.526	12.029	58.876
3	1.495	7.117	65.993	1.495	7.117	65.993

Table 5 presents the factor loading values for the three components of the self-regulated learning construct. Analysis using the Varimax rotation matrix reveals that 20 items have factor loading values exceeding 0.6, ranging from 0.665 to 0.847 [37,39]. However, item PM12 has a factor loading value below 0.60 and will therefore be excluded from the field study. As a result, 20 items are retained, confirming their suitability for the self-regulated learning construct.

Table 5
Factor loadings for the self-regulated learning construct components

Construct	Component		
	1	2	3
DP1	.802		
DP2	.704		
DP3	.787		
DP4	.758		
DP5	.755		
DP6	.804		
DP7	.759		
DP8	.813		
PM9		.665	
PM11		.847	
PM12		.591	
PM10		.824	
PK13			0.803
PK14			0.741
PK15			0.790
PK16			0.748
PK17			0.711
PK18			0.676
PK19			0.741
PK20			0.757
PK21			0.749

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

3.4 Finding for the Field study

Using the results from the EFA, this study developed the final questionnaire for the field study. The questionnaire for self-regulated learning now consists of three components, retaining 20 items with factor loading values above 0.6. The first component, self-motivation, comprises eight items. For the second component, metacognitive planning, one item (PM12) was dropped due to its factor loading being less than 0.6, leaving three items. The third component, metacognitive monitoring, includes nine items. Data collection involved 435 respondents.

The study confirms the measurement model for self-regulated learning as a second-order construct measured through three components. The CFA procedure was conducted using IBM-SPSS-AMOS 24.0 with the Maximum Likelihood Estimator (MLE) algorithm, known for its speed, efficiency, and accuracy [29]. The CFA results indicate that the self-regulated learning construct comprises three components, as shown in Figure 1. Each component is measured using several items in the questionnaire. Figure 1 illustrates the initial measurement model for the second-order self-regulated learning construct, with the components and their respective items: DP (eight items), PM (three items), and PK (nine items).

The initial CFA analysis to confirm the measurement model for the self-regulated learning construct found that two items had factor loadings below 0.6. Therefore, items PK12 and PK18 from the metacognitive monitoring component were removed. Additionally, the fit indices for the initial measurement model did not meet the required level. Therefore, modification indices (MI) were examined. If MI > 15, the items are overlapping. MI for items DP7 and DP8 from the self-regulation motivation component was the highest. Item DP7 was dropped due to its lower factor loading compared to DP8. After repeating the CFA analysis, the MI for items PK19 and PK20 remained high. Consequently, item PK19 was removed based on its lower factor loading compared to item PK20.

3.5 Construct Validity Assessment for the Constructs

To ensure the validity and reliability of the instrument for measuring the self-regulated learning construct, the CFA procedure was conducted. According to Zainudin Awang *et al.,* [29], construct validity is assessed through fit indices. There are three categories of fit indices to be met: absolute fit, incremental fit, and parsimonious fit. Items with factor loadings below 0.6 will be removed as they do not contribute to the construct measurement [40]. In this process, four items (PK12, PK18, PK19, and DP7) were removed, and the CFA analysis was repeated until the measurement model achieved satisfactory fit.

The initial CFA model (Figure 1) involved 20 items categorized into three components: self-regulation motivation, metacognitive planning, and metacognitive monitoring. After item removal, the final CFA model (Figure 2) involving 16 items showed a significant improvement in model fit. The fit indices values for the model are presented in Table 6.

Table 6
Model fit indices

Name of Category	Fitness Index	Level of Acceptance	Initial measurement model	Final measurement model
Absolute Fit	RMSEA	< 0.08	0.086	0.076
Incremental Fit	CFI	> 0.90	0.890	0.935
	TLI	> 0.90	0.875	0.923
Parsimonious Fit	Chisq/df	< 5.0	4.228	3.510

Figure 2 presents the revised final measurement model for the self-regulated learning construct, where all factor loading values for items in each component exceed 0.60. This final model was developed after the item removal process to achieve unidimensionality and meet the established fit index criteria. As a result, the final model features fewer indicators compared to the original model.

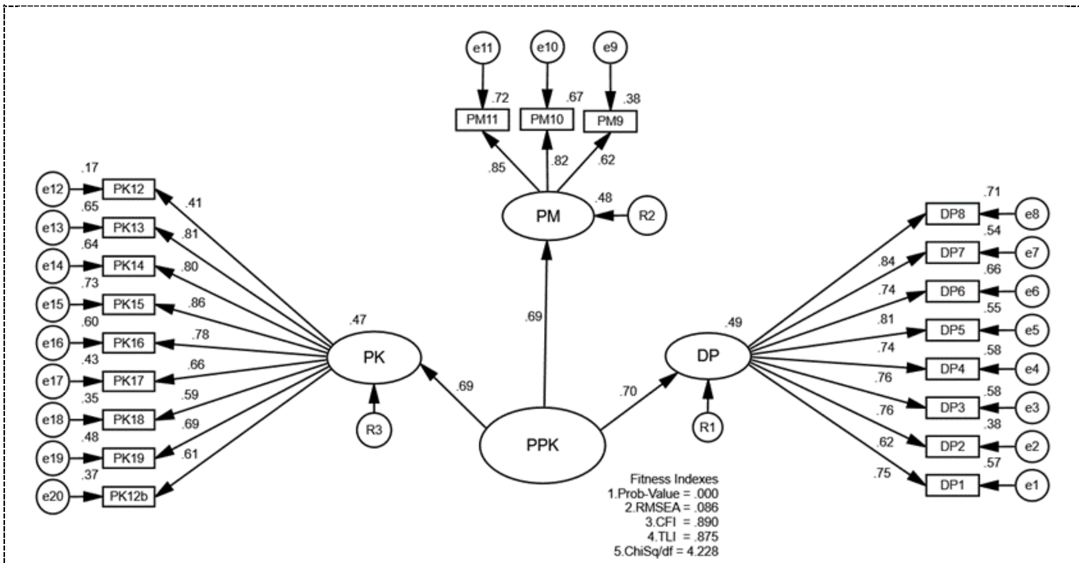

Fig. 1. Initial Measurement model for the second-order self-regulated learning construct

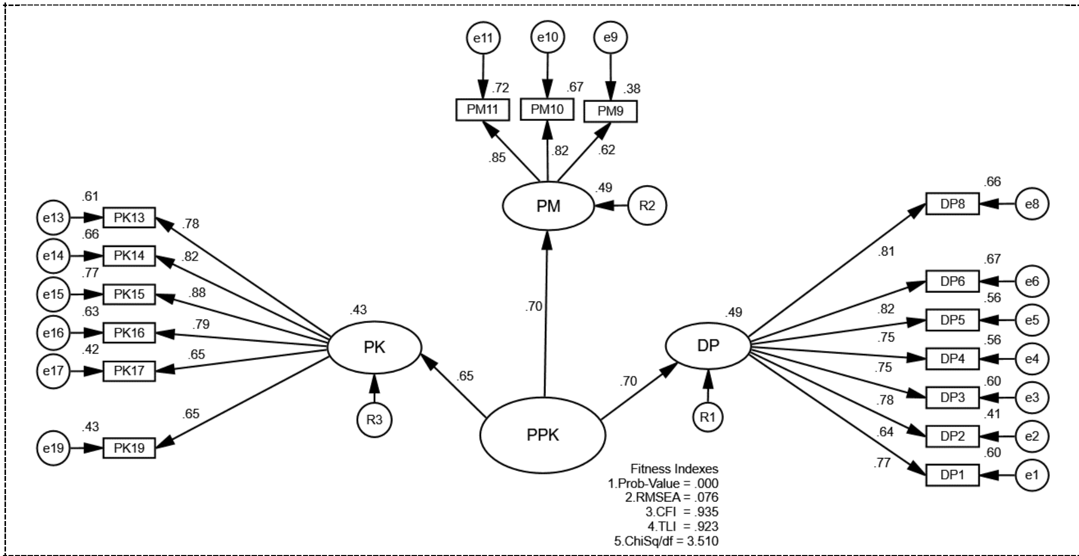

Fig. 2. Final measurement model for the second-order self-regulated learning construct

3.6 Convergent Validity and Composite Reliability Assessment for the Constructs

Convergent validity for the self-regulated learning construct was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). CR measures the internal consistency of the items within the construct, while AVE evaluates the extent to which the items contribute to the construct's variance. The results in Table 7 indicate that convergent validity and composite reliability for the self-regulated learning construct have been achieved, with all CR values exceeding 0.5 and all AVE values exceeding 0.6 [41].

All AVE values surpass 0.5, demonstrating that each construct meets the necessary criteria for convergent validity [40]. This confirms that the instrument is capable of accurately and consistently measuring the self-regulated learning construct.

Table 7
Convergent validity and composite reliability

Construct	Item	Factor Loading	CR (Above 0.6)	AVE (Above 0.5)	$\sqrt{\mathbf{AVE}}$
Self-Motivation	DP1	0.772	0.579	0.906	0.952
	DP2	0.642			
	DP3	0.776			
	DP4	0.751			
	DP5	0.746			
	DP6	0.818			
	DP8	0.81			
Metacognitive Planning	PM9	0.616	0.590	0.809	0.899
	PM10	0.82			
	PM11	0.847			
Metacognitive Monitoring	PK13	0.782	0.588	0.894	0.946
	PK14	0.815			
	PK15	0.879			
	PK16	0.795			
	PK17	0.65			
	PK19	0.653			

Another important aspect of validity assessment is discriminant validity. Given that self-regulated learning is a second-order construct with three components, this study needs to evaluate the strength of the correlations among these components. Discriminant validity for the self-regulated learning construct is achieved if the correlation coefficients between components do not exceed 0.85 [42]. Figure 3 presents the discriminant validity assessment for the self-regulated learning construct. Table 8 shows the discriminant validity indices for the self-regulated learning construct. The diagonal values in the matrix represent the square root of the AVE for the three constructs, and the values are the correlations between each pair of constructs. If the diagonal value is higher than the values in the corresponding row or column, discriminant validity is achieved. The study found that all three constructs in the model meet the criteria for discriminant validity.

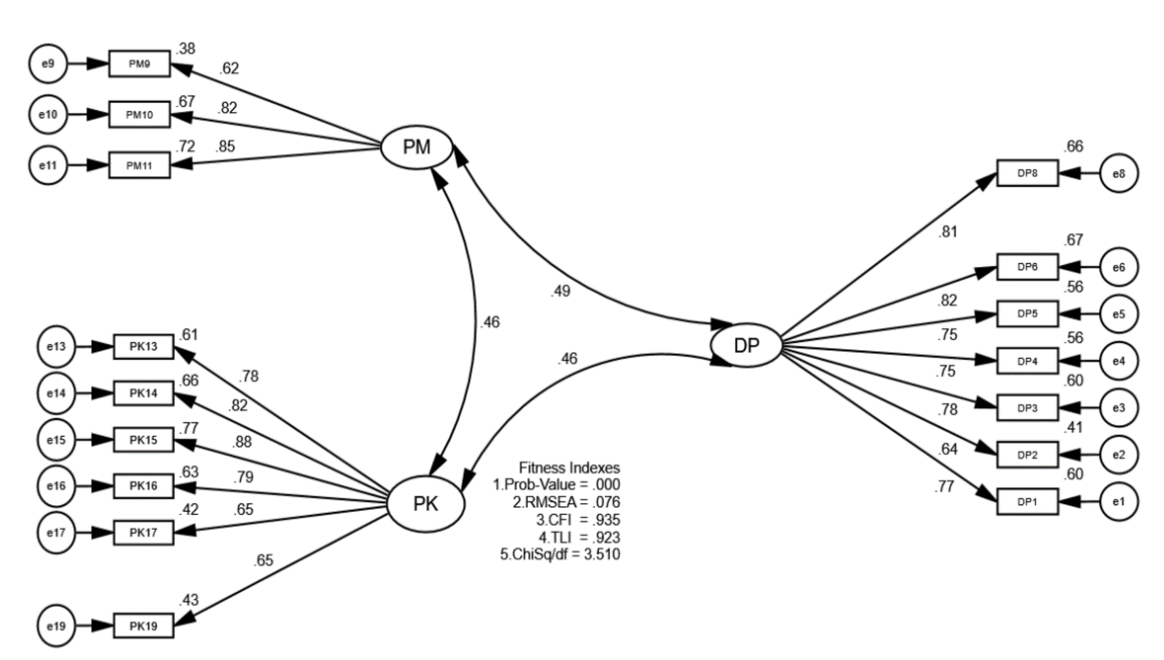

Fig.3. Assessment of discriminant validity for the self-regulated learning construct

Table 8
Discriminant validity index for the self-regulated learning construct

Konstruk	Self-Motivation	Metacognitive Planning	Metacognitive Monitoring
Self-Motivation	**0.952**		
Metacognitive Planning	0.488	**0.899**	
Metacognitive Monitoring	0.458	0.455	**0.946**

4. Conclusion

This study aimed to confirm the validity and reliability of the self-regulated learning instrument through Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) procedures. The results indicate that the instrument effectively measures three main components of self-regulated learning: regulation motivation, metacognitive planning, and metacognitive monitoring. EFA revealed a clear factor structure with 21 items forming the three main components. However, one item, PM12, was removed due to a factor loading value of less than 0.6. This removal enhanced the factor structure validity of the instrument. CFA was then conducted to confirm the factor structure identified through EFA. The CFA results indicated that four items, PK12, PK18, PK20, and DP7, needed to be removed to ensure a better and more fitting model. After removing these items, 16 items remained in the validated instrument. The CFA results were also used to perform Structural Equation Modeling (SEM) to test the proposed theoretical model. The removal of several items in both analyses indicates that the validated instrument has a more robust and reliable structure for measuring students' self-regulated learning in physics education. This refined instrument can be used by researchers and educators to more accurately and consistently assess students' self-regulated learning levels.

4.1 Implications and Further Recommendations

The use of Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) in research is crucial to ensure that measurement instruments possess high validity and reliability. Without EFA, there is no guarantee that the items in the instrument measure the intended construct; EFA aids in identifying the underlying factor structure of the items, while CFA confirms that the model obtained through EFA is consistent with the collected data. This validation is vital because, without CFA, the factor structure identified by EFA may not be valid, potentially leading to instruments that inaccurately or inappropriately measure the intended constructs. Consequently, this can result in unreliable research findings and misleading conclusions.

Furthermore, the absence of EFA and CFA can lead to instruments producing inconsistent or inaccurate results when applied in different contexts or populations. Using an invalid instrument may also lead to ineffective intervention planning, as the results obtained might not reflect the actual situation. Therefore, not employing EFA and CFA can significantly affect research outcomes and conclusions. These procedures are essential for ensuring that measurement instruments are accurate, valid, and reliable. Without confirmed validity and reliability, any decisions or interventions based on such instruments may be ineffective or misleading. To mitigate these risks, researchers must prioritize the use of EFA and CFA in their studies. Future research should also consider additional validation methods, such as cross-validation with different samples or the integration of qualitative data to enhance the robustness of their measurement instruments. By doing so, researchers can ensure that they yield reliable and valid results that inform effective interventions and contribute meaningfully to the body of knowledge in their respective fields.

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