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Measuring Self-Regulated Learning in the STEM Framework: A Confirmatory Factor Analysis

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Abstract: Within the context of Self-Regulated Learning (SRL), a process of directing oneself to facilitate individual learning more effectively, the SRL instrument development is deemed necessary to measure students' self-reliance in learning mathematics in the science, technology, engineering, and mathematics (STEM) framework. The research aims to develop and test the validity and reliability of an SRL instrument, namely a 14-item SRL questionnaire accommodating four aspects, namely planning, self-monitoring, self-controlling, and evaluation. The study involved 420 junior high school students in East Java, Central Java, and Yogyakarta Special Region. The results show that the questionnaire was developed as planned and that planning, monitoring, controlling, and evaluating aspects can reflect the SRL variable in a valid, reliable, and significant way supported by each aspect's behavior indicator. The SRL variable theoretical model corresponds (good fit) with the empirical data, and all of the items are likely valid and reliable to assess student's mathematics SRL in the STEM framework. The SRL questionnaire was also found suitable for use by teachers to measure junior high school students' self-reliance in SRL.

Keywords: *Confirmatory factor analysis, reliability, self-regulated learning, STEM, validity.*

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Introduction

It is widely accepted that learning must be able to prepare students to face the times and that effective learning requires much support from many parties, especially teacher's innovation and student's awareness. Some students' awareness components beneficial for successful learning are perhaps self-regulated learning (SRL), self-efficacy, motivation, and so forth. SRL is an essential factor possessed by students for learning to be effective. Some may find SRL positively connected with the execution and ability level in various realms, like game, music, and scholarly accomplishment (Retnawati, 2016b). Students with excellent self-regulation are therefore considered as individuals who are proactive in completing their assignments. It means that they take individual responsibility, diligence, and versatile ability due to a positive metacognitive strategy and inspirational belief (Schunk & Zimmerman, 2007). The self-regulated process does not instantly produce high-level skills but helps people gain knowledge and skill more effectively (Butler, 2002).

It was claimed that SRL is a key 21st century skill for independent students (Stehle & Peters-burton, 2019) and affirmed that it becomes one of the attributes that professionals need from science, technology, engineering, and mathematics (STEM) in the coming years are abilities, other than the capability to continually gain knowledge (Felder & Brent, 2016). This is perhaps because SRL plays a vital role in completing interdisciplinary assignments in STEM learning (Zheng et al., 2020), specifically in terms of efficiency and student performance when finishing techniques of design projects (Lawanto & Johnson, 2012). STEM assignments or projects are usually designed to encourage learners to think and learn divergently with real-world contexts. Therefore, these assignments emphasize the independent role of students to construct meaning in unique ways, take learning steps, make a decision and evaluate learning outcomes (Li et al., 2020). When students accomplish STEM assignments or projects, SRL empowers them to take ownership of

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learning, while teachers having experience with STEM subjects are more likely to enhance the SRL skills of their learners.

SRL is closely related to some other terms, such as self-regulated learning, self-directed learning, self-regulated thinking, self-efficacy, and self-esteem. Some consider SRL as involving a process that allows a person to control the mind, feeling, and action, and allows an individual to acclimate to their community and physical contexts. In a learning context that refers to a process, SRL is pointed out to oneself, allowing the student to change the mental ability into performance skill (Zimmerman, 2000). SRL can contribute to an individual's ability and prospects for succeeding by improving their capability more efficiently (for instance, Zimmerman, 2006). It is then perceived that instruments that measure SRL can identify individual strengths and weaknesses related to the study. The information later can help people learn more effectively, which eventually improves their problem-solving skills, higher critical thinking skills through mastering assignments, and measuring self-regulated learning as a generally steady component of a person in many areas. Such SRL instruments seek to find out aspects of student learning independence that should need to be improved and how to improve these aspects so that students can manage themselves in learning (Zimmerman, 1989a, 2006). Research on students' SRL likely reveals variables, namely the resulted motivation (or effort) and self-efficacy (Sungur & Tekkaya, 2006). The results are also positively related to cognitive and metacognitive strategies (Pintrich, 2004; Schunk, 1989). Students are therefore encouraged to always try maximally to improve and maintain their effort to keep self-regulated for years to reach optimum performance level.

To measure cognitive abilities and attitudes, including self-regulated learning in the STEM framework, a valid and reliable instrument is highly required (Otaya et al., 2018; Retnawati, 2016a). Currently, the existing self-reporting instrument only measures SRL particular-domain (for example, Fontana et al., 2015; Li et al., 2020; Pintrich et al., 1993; Retnawati, 2016b; Zimmerman & Martinez-Pons, 1988). Fontana et al. (2015) has developed the SRL questionnaire to provide a measure of self-regulated learning behaviour in the workplace. The SRL questionnaire consists of three phases, namely forethought, performance, and self-reflection. Li et al. (2020) also developed an SRL instrument to measure the temporal dynamics of SRL behavior in STEM learning which consists of forethought, performance, and self-reflection phase. Similarly, Retnawati (2016b) developed an SRL instrument for mathematics education students consisting of a Likert scale and multiple-choice questions. The SRL instrument consists of three components, namely thought, performance, and self-reflection. It entails the writers developing an instrument of self-regulated learning in STEM framework as a valid and reliable instrument. The research subjects were junior high school (JHS) students that were in the transition stage from their childhood to adulthood. At these ages, JHS students mostly need teacher assistance to develop their SRL, so that such a quality instrument is inevitably required for that need. Hence, this study was carried out to develop an SRL assessment instrument in the STEM framework and examine its quality.

The Research Objectives

Based on the introduction and theoretical study above, the present study aims to:

1. develop a standardized questionnaire of self-regulated learning in the STEM framework,
2. find out the construct validity of the questionnaire of self-regulated learning using confirmatory factor analysis (CFA), and
3. determine the reliability of the questionnaire of self-regulated learning using confirmatory factor analysis (CFA).

Literature Review

STEM Framework

STEM education is instrumental to be applied in the classroom because, in everyday life, many multidimensional problems cannot be partially solved only with science, technology, mathematics, or engineering, but all four must be simultaneously orchestrated. It is designed to achieve educational goals, namely to prepare students to face life in the future both in terms of knowledge, skills, and attitudes, including self-regulation, motivation, and others. Students should be able to integrate and apply STEM concepts and procedures in order to have equal opportunities to participate in real-world interdisciplinary scenarios.

Furthermore, STEM education is necessary to prepare students for complex future life and intense global competition. The four disciplines in practice are interrelated and cannot work alone to solve daily problems. However, the four have been studied separately in practice, so they are only partially understood in theory. These four fields of study must be learned by students both in theory and in implementation to solve problems in their daily life, which is possible if they can relate the four lessons. The linkage of the four, hence, must be made explicit, which is sometimes dominated by one subject in the form of structured learning activities.

Banks and Barlex (2014) think that the framework includes some highly qualified activities that can develop independent students. Those are self or group investigations, investigations encouraging teams of people working together with members who are fully aware of their specific role in planning, implementation, interpretation, and working communication, also extensive investigations or projects developing independent learning and opportunities to make decisions. Besides, self-regulated students usually actively plan their approach to problem-solving skills, monitor their progress, and reflect their work with feedback (Zimmerman, 2000). During the SRL process, a student strengthens self-motivation to improve impulse control to solve problems efficiently (English & Kitsantas, 2013). Integrating independent learning strategies, therefore, supports students to become actively involved in the process of encountering difficulties during the learning process (Boekaerts, 2016), and provides adequate practical experiences for students to develop *self-efficacy*, *self-regulated learning,* and maintain the personal identity of students as practical people (Banks & Barlex, 2014). STEM learning activities demanding independent learning for students (Felder & Brent, 2016) include (a) identifying learning needs, b) setting learning goals, (c) identifying and accessing learning resources, (d) selecting and implementing learning strategies; and (e) evaluating learning outcomes.

Self-Regulated Learning

Bandura (1986) specifically defines SRL as the student's situation who learns to take an active part to arrange their studying activities, monitor motivation and academic purpose, manage human resources and learning resources, and become an active executor in the decision-making its implementation in the learning process, while Zimmerman defines SRL as the ability of the student to engage in the education process actively, metacognitively, motivationally, and behaviorally (Cleary & Zimmerman, 2004; Zimmerman, 1989a). Schunk and Zimmerman further define SRL as a learning process that occurred because of the influence of their mind, feeling, strategy, and behavior, which is oriented to achieving the purpose, and it is an activity of monitoring, directing, and managing actions to obtain information, expand skills, and improve oneself (Winne & Hadwin, 2008). Self-regulated learning is a student's active and constructive process in determining learning objectives, planning learning strategies, implementing those strategies to monitor and control their cognition and motivation, and evaluating the process to obtain the best learning strategy.

Because the feedback from the initial skill is utilized to decide to repeat the efforts, SRL is a cyclic process (Retnawati, 2016b). Bandura suggests three phases of SRL, i.e., (1) self-observation, (2) self-assessment, and (3) self-reaction (Bandura, 1986; Schunk, 2012). Besides, Zimmerman (1989a, 1989b, 1990, 2000) divided phases of SRL into three-phase, that is, phases of thinking, performance/volitional control, and self-reflection. Afterward, Boekaerts and Rozendaal (2007) suggest self-regulated learning stages, namely identifying goal setting, goal striving, and performance feedback. Meanwhile, Zumbrunn et al. (2011) reveal three SRL phases, i.e., forethought and planning, performance monitoring, and reflection on performance. Efklides (2011) suggests SRL stages, such as task representation, cognitive processing, and performance. Winne and Hadwin (2008) similarly divides self-regulated learning phases into task definition, goal setting and planning, technique and strategy application, and metacognitive strategy adaptation. Likewise, Hadwin et al. (2011) break down self-regulated learning stages into the planning and control stages and regulating stage. In clear perspective, Panadero's review (2017) reveals that mostly the models were built from three phases: preparation, performance, and assessment.

Regarding this, an investigation conducted by Li et al. (2020) revealed the temporal dynamics of SRL behavior in implementing STEM learning. These researchers utilized an SRL instrument containing 3 phases, namely forethought, performance, and self-reflection phase adapted from SRL instruments used to thoroughly investigate students' self-regulated learning behaviors in engineering design. The research compared three groups that are unsuccessful, success-oriented, and mastery-oriented in SRL competency, actual SRL behaviors, and SRL networks. The study likely finds that (1) there is no significant difference in SRL competency but is quite different in SRL behavior because success-oriented and mastery-oriented groups performed better than the unsuccessful group in behavior evaluation. Besides, (2) mastery-oriented group seems to have a stronger interaction than do success-oriented and unsuccessful groups, and (3) there are few similarities among those groups, but in general they are different at all.

Another researcher, Retnawati (2016b), has successfully proved the content validity of a self-regulated learning questionnaire based on experts' judgment using Aiken and the Expanded-Gregory formula. The utilized SRL-scale in that study was developed in the form Likert-scale and multiple-choice items, and it contained three components. They are elements of thought which contains task analysis and confidence indicators, the component of performance control with self-control and sufficient observation indicators, and the component of self-reflection having self-consideration and self-reaction indicators. The result of that study proved that the developed instrument items are somewhat valid and have good content validity, but then a further investigation is needed ensure its construct validity.

In the meantime, based on Zimmerman's theory, Fontana et al. (2015) constructed and validated of the self-regulated learning at work questionnaire to provide a measure of SRL behaviour in the workplace. The SRL questionnaire consists of three scales based on the three phases of the SRL (forethought, performance, and self-reflection). The forethought phase measurement scale consists of 17 items representing four sub-processes. The scale in the performance phase contains 19 items representing five sub-processes. Finally, the scale in the self-reflection phase consists of six items representing two sub-processes.

The researchers later constructed a list of SRL indicators based on self-regulated learning aspects from Bandura (1986), Efklides (2011), Hadwin et al. (2011), Pintrich (2004), Schunk (2012), Winne and Hadwin (2008), Zimmerman (2000), and Zumbrunn et al. (2011). Developing those indicators, the researchers found four aspects, namely planning, monitoring, controlling, and evaluating as presented in Table 1. This table demonstrates that each aspect of planning and monitoring has 4 indicators and each aspect of controlling and evaluating has 3 indicators.

Table 1. Result of SRL Synthesis Indicator

Aspect	Indicator
Planning (A)	a. Determining objectives to be achieved (A1) b. Planning completion strategies (A2) c. Understanding the task (A3) d. Assessing self-believe (A4)
Monitoring (B)	a. Applying strategies (B1) b. Monitoring motivation and effort (B2) c. Monitoring self-behavior (B3) d. Monitoring strategy effectiveness (B4)
Controlling (C)	a. Selecting and adapting strategies (C1) b. Managing motivation and influence (C2) c. Self-control toward behavior & increasing/decreasing effort (C3)
Evaluating (D)	a. Evaluating performance on learning the task (D1) b. Learning from mistakes (D2) c. Adaptation (D3)

The following is an example of a statement in an SRL questionnaire based on able 1:

A1: I design my learning goals/targets before learning activities begin,

B4: I check the progress of my assignment to reflect on how well my strategy works.

Methodology

Sample of Research

Participants in this research are 420 students at Madrasah Tsanawiyah (MTs) and Junior High School (JHS) located in Central Java, East Java, and Yogyakarta Special Region. Participants were randomly selected with a population-based sampling on school, gender, and region. The participants consist of 193 MTs students (46%), and 227 JHS students (54%). In terms of gender, 184 students (43.8%) are male, and 236 students (56.2%) are female. They are spread over grade VII with 134 (32%) students, grade VIII with 189 (45%) students, and grade IX with 97 (23%) students.

Instrument and Procedures

The present study employs an SRL-scale instrument to assess students' self-regulated learning. The SRL aspects included are planning, monitoring, controlling, and evaluating (see Table 1). Every aspect is assessed through three or four statements or items. Planning is a form of self-regulation in understanding learning purposes and emerging self-confidence. Monitoring can be seen as a self-observing activity in completing learning tasks. Then, controlling means a self-regulating activity to maintain self-motivation in competing for the tasks, and evaluating in this context refers to the self-evaluation and self-reflection activities toward the success and failure in solving the final tasks. The instrument utilized the Likert scale with four categories. The answer "always" scores four or scores one for unfavorable statements, "often" scores three, but scores two for unfavorable statements, "rarely" is given a two-score, but scores three for unfavorable statements, and "never" is given one score, but scores four for unfavorable statements.

Validity is the conformity between the test value interpretation and its purposes based on evidence and theory (Mardapi, 2017). The instrument validation process can be carried out by verifying components and processes (internal validation) and confirming the use of impact models (external validation) (Richey, 2005). The validity of an instrument consists of criteria validity, content, and construct (Retnawati, 2016a). Content validity is based on expert agreement by conducting instrument assessment by experts in terms of component, structure, and usage in the future. An instrument is valid if the experts believe that the instrument measures the mastery of the competencies identified in the psychological domain or psychological construct (Retnawati, 2016a). A validity index, such as the one established by Aiken (1985), can be used to determine agreement. The attitude scale is validated by five validators consisting of lecturers majoring in mathematics, psychology, and linguistics. Validators selected the answers by noticing the compatibility aspects, indicators, and statements. All items were found valid because their Aiken's coefficient value is $V \geq 0.75$ with five validators and four-option answers (Aiken, 1985).

Meanwhile, construct validity is an interpretation of validity of assessment results by proofing measurement score significance (Retnawati, 2016a). The construct validity test can be done by verifying that the constructed instrument exists, and then its measurement result is empirically proven. The construct validity verification was conducted in this research, i.e., through validator assessment analyzed by using Aiken's coefficient and CFA test. Besides validity, a good instrument must also notice instrument reliability. Reliability means how far measurement result has reliable credibility, reliability, constancy, consistency, and stability (Chakrabartty, 2013). The testing of consistency described earlier means that the test will produce equal or nearly comparable results if the same assessment property is repeated (Dewanti et al., 2021). Reliability also refers to the measurement consistency in terms of results with the same value and level without bias by ensuring consistent time measurement.

Data Analysis

Construct validity and reliability of the indicators (items) form the latent construct by conducting Confirmatory Factor Analysis (CFA). Instrument validity and reliability tests were conducted by CFA to obtain valid and reliable data. In other words, the tests were used to undertake model measurement to describe how well the aspects and indicators can be used as a self-regulated learning assessment instrument.

According to Hair et al. (2014), CFA should not only be conducted through the Construct Validity test but Construct Reliability (CR) test as it seeks to examine the load factor value (> 0.4) and t-count value is (> 1.96). Concerning this, Sharma (1996) and Retnawati (2016a) explain that the weakest acceptable factor is 0.40. As for the reliability, Hair et al. (2014) state that a construct has good reliability if its CR value is ≥ 0.70 and the variance extracted (VE) value is ≥ 0.50. This construct reliability value can be calculated by using the following formula (Hair et al., 2014; Retnawati, 2016a; Wijayanto, 2008).

$$CR = \frac{(\sum SLF)^2}{(\sum SLF)^2 + (\sum e)}$$

While variance extracted value uses the following formula (Hair et al., 2014; Wijayanto, 2008)

$$VE = \frac{\sum SLF^2}{\sum SLF^2 + (\sum e)}$$

Remark:

CR : Construct Reliability

VE : Variance Extracted

SLF : Each item's standard loading factor value

e : Each item's error value

Then the data obtained were analyzed by Confirmatory Factor Analysis (CFA) using LISREL version 8.50.

Results

In this research, the CFA test aimed to determine a good model's construct validity and conformity. The variable used in this research was the self-regulated learning (SRL) variable consisted of 4 constructs, i.e., planning, monitoring, controlling, and evaluating. Every SRL construct consists of several indicators explained within the model identification. The CFA test was conducted on the data derived from 420 analysis using LISREL version 8.50. The display of the CFA analysis result is presented in Figure 1.

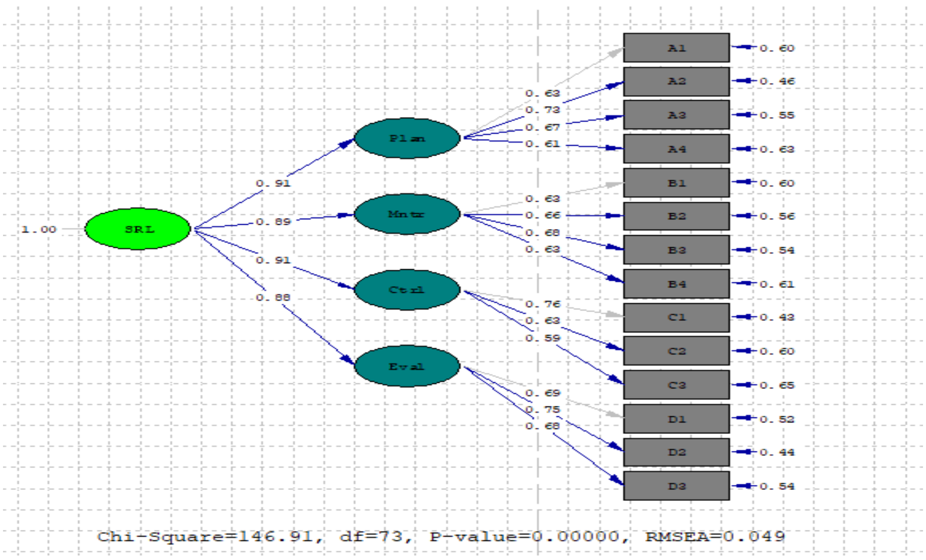

Figure 1. CFA Output (Standardized Solution)

Firstly, described is the model test generated in the CFA analysis. Based on Figure 1, it appears that the model does not fit because they have not met the criteria used; among others are due to the p-value = 0.00000 < 0.05 and Chi-Square value = 146.91 > 2df (df = 73).

Next to reveal is the modification index to obtain the suggested model improvement. After a modification, the standard solution is presented in Figure 2. From Figure 2, the adaptation indicator (D3) is included in controlling and evaluating this happens because the statement D3 ('when I find a strategy that is proven to be effective, I will use it again in another projects/tasks') seems to have similarities with the statements of indicators C1 ('I choose the best strategy and implement that strategy maximally to complete the projects/tasks') and C3 ('I record my successes and failures in completing projects/tasks') on the controlling aspect. Because the loading factor value between the controlling aspect and the D3 indicator is 0.28 < 0.40, the D3 indicator remains in the evaluating aspect.

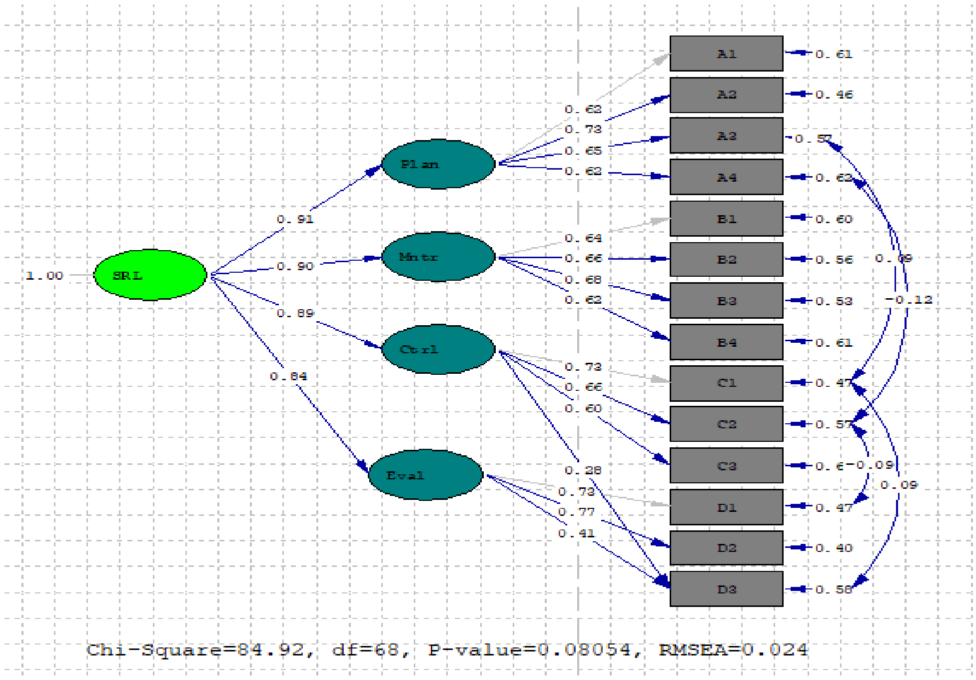

Figure 2. CFA Modification Output (Standardized Solution)

In Figure 2, it is clear that the Chi-square value is = 84.92 < 2df (df =68) and p-value = 0.08054 > 0.05 (good fit). Overall, based on the LISREL output, GOF values (Goodness of Fit) obtained are as follows:

Table 2. Goodness of Fit of the CFA Model

Number	GOF Indicator	Acceptable Index	Model Index	Explanation
1	Chi-Square	< 2 df	84.92 < 2(68)	Good Fit
2	Probability (p-value)	≥ 0.05	0.081	Good Fit
3	RMSEA (Root Mean Square Error of Approximation)	≤ 0.08	0.024	Good Fit
4	RMSR (Root Mean Square Residual)	≤ 0.05	0.022	Good Fit
5	NFI (Normed Fit Index)	≥ 0.09	0.96	Good Fit
6	CFI (Comparative Fit Index)	≥ 0.09	0.99	Good Fit
7	IFI (Incremental Fit Index)	≥ 0.09	0.99	Good Fit
8	GFI (Goodness of Fit Index)	≥ 0.09	0.97	Good Fit
9	RFI (Relative Fit Index)	≥ 0.09	0.94	Good Fit
10	AGFI (Adjusted Goodness of Fit Index)	≥ 0.09	0.96	Good Fit
11	PGFI (Parsimony Goodness of Fit Index)	≥ 0.06	0.63	Good Fit
12	NNFI (Non-Normed Fit Index)	≥ 0.09	0.99	Good Fit
13	PNFI (Parsimony Normed Fit Index)	≥ 0.06	0.72	Good Fit
14	CN (Critical N)	≥ 200	465.14	Good Fit

*Fit criteria is based on Widowati et al. (2021)

According to Widowati et al. (2021), there are at least 14 indicators that designate the criteria of "good fit" as presented in Tabel 2. The table shows that all of the indicators meet the criteria of a good model fit, so the model does "fit" (Tentama & Subardjo, 2018; Widowati et al., 2021).

As the model is found compatible, an analysis was later conducted to prove its construct validity. Proving the construct validity was conducted by looking at the standard loading factor value of each aspect or indicator. If the value of standard loading factor is ≥ 0.40, an indicator or aspect is said to be valid (Retnawati, 2016a; Sharma, 1996). Based on the analysis results, Table 3 shows that the CFA output in standardized solution shows that all aspects have a loading factor of ≥ 0.40; that is 0.91 for planning, 0.90 for monitoring, 0.89 for controlling, and 0.84 for the evaluating aspect. Hence, it can be said that all of the four indicators are valid to describe the SRL model.

Table 3. Analysis results of the 2nd Order CFA Construct Validity of SRL (Latent-Aspect)

No	Aspect	Loading Factor	t-Value	Remark
1	Planning	0.91	12.14	Significant
2	Monitoring	0.90	12.23	Significant
3	Controlling	0.89	13.99	Significant
4	Evaluating	0.84	12.82	Significant

The next analysis carried out aimed to check to construct validity in each SRL item. The CFA analysis was conducted from the latent aspect construct to its indicators mentioned in Table 4. An item can be said to be valid if the loading factor is > 0.4, and it was found in Table 4 that the loading factor of the 14 items is > 0.6, except for one item which has a factor of 0.41, namely adaptation.

Table 4. SRL Validity and Reliability from the CFA Results

Latent	Construct	Error var	Std Loading	Validity Category	CR	VE	Reliability Category
Planning (A)	A1	0.61	0.62	Valid	0.75	0.54	Reliable
	A2	0.46	0.73	Valid			
	A3	0.57	0.65	Valid			
	A4	0.63	0.62	Valid			
Monitoring (B)	B1	0.60	0.64	Valid	0.75	0.53	Reliable
	B2	0.56	0.66	Valid			
	B3	0.53	0.68	Valid			
	B4	0.61	0.62	Valid			
Controlling (C)	C1	0.47	0.73	Valid	0.70	0.54	Reliable
	C2	0.57	0.66	Valid			
	C3	0.65	0.60	Valid			
Evaluating (D)	D1	0.47	0.73	Valid	0.72	0.57	Reliable
	D2	0.40	0.77	Valid			
	D3	0.58	0.41	Valid			

*The criteria of "Valid" are fulfilled if the loading factor value is ≥ 0.4.
* The criteria of "Reliable" are fulfilled if the CR is ≥ 0.7 and VE is ≥ 0.5

The next step carried out was aimed to check the SRL instrument's reliability, which has been arranged. The construct reliability (CR) and variance extracted (VE) were used to assess the instrument's reliability. The CR and VE calculation results are displayed in Table 4. The SRL instrument is stated "reliable" if all of its aspects have CR and VE values of ≥ 0.7 and ≥ 0.5, respectively. Table 4 clearly indicates that the CR value of the four self-regulated learning instrument aspects ranges from 0.70 to 0.75, meaning that they meet the minimum limit of 0.70. Meanwhile, dividing the mean root of the standard loading factor by the number of indicators aimed to get the VE to demonstrate the latent variable value's capacity to represent the existing score of data. The greater the value of VE, the higher its ability to explain the indicator's value in measuring the latent variable. The analysis result in Table 4 shows that the VE value of the four self-regulated learning aspects is 0.53 – 0.57, meaning that it meets the VE minimum criteria of 0.5. Therefore, the four SRL aspects can be declared to have good reliability. The results also confirm that the instrument is highly consistent, allowing it to be used on numerous occasions with various samples.

Discussion

The input and suggestions were put into the revised version corresponding to the experts' remarks. After being improved, the questionnaire was declared valid as proved by the Aiken's index of 0.8 (Retnawati, 2016a), and it can be used in the next step, which was an empiric test through trials. The field test is conducted on 420 JHSs and MTs students in Central Java, East Java, and DIY. The analysis result shows that out of 14 items developed to meet the fit model. The fit model criteria used is the 18 criteria (Widowati et al., 2021), with the p-value of 0.08054 > 0.05, RMSEA 0.024 < 0.08, Chi-Square < 2df of 84.92 < 2 (68) and Goodness of Fit Index (GFI) of 0.97 > 0.90 (Schermelleh-engel et al., 2003). In general, Goodness of Fit has been met because the calculated value is within the specified range, indicating that the model is "fit". As a result, the study indicates that the model fits, denoting that the instrument's construct is good and appropriate in this assessment model.

Furthermore, the CFA shows that the four-factor model is likely compatible with the acceptable data. The analysis result shows that the planning aspect's four items can significantly increase model conformity and weighting. Planning includes activities such as determining purpose, planning strategy, understanding assignment, and self-efficacy assessment. The view corresponds to Bandura and Zimmerman that planning is an individual's belief that they can successfully undertake the requested attitude to perform specific tasks (Bandura, 1986; Panadero, 2017; Zimmerman, 2000). The planning aspect is also called as identification aspect (Boekaerts & Corno, 2005), forethought (Pintrich, 2004; Zimmerman, 2000), or self-observation (Bandura, 1986). The second factor, namely monitoring, comprises four items to meet the expected validity and reliability criteria. Four items on the monitoring factor are the students' activity statement in applying strategies, monitoring motivation, monitoring behavior, and examining strategy effectiveness. It corresponds with the monitoring description, a performance monitoring activity, using strategies, monitoring effectiveness, and self-motivation to complete tasks according to the purpose they have set (Kesuma et al., 2020; Zumbrunn et al., 2011). The third factor is controlling. The controlling factor analysis shows that the three items made are valid and reliable. The third factor is controlling, an activity of selecting and adapting strategies, managing motivation, and self-controlling. The three controlling items in this aspect correspond to the notion that the controlling phase is a selection phase & learning strategy adaptation (Pintrich, 2004), self-controlling (Butler, 2002), and controlling motivation/emotion (Winne & Hadwin, 2008). Hence, when learning is regarded below the standard, the students can decide to review the content, adjust their expectations, revise the difficulty level, and look for additional materials (Kesuma et al., 2020). The fourth factor is evaluating, which consists of performance evaluation, learning from mistakes, and adaptation. The evaluating stage is also called as performance feedback stage (Boekaerts & Corno, 2005), reaction and reflection stage (Pintrich, 2004), adapting metacognition stage (Winne & Hadwin, 2008), or self-reflection stage (Zimmerman, 2000). The three items in this aspect are compatible with their notion. It corresponds to Winne and Hadwin's (2008) opinion that the final stage in SRL contains the ability to adapt to the strategy used or, as in Zimmerman (2000), that SRL's final stage is the ability to self-evaluate skill, or learning from the previous mistake.

SRL construct validity is supported by the fact that the model is based on the theory of Bandura, 1986; Pintrich, 2004; Schunk, 2005; Zimmerman, 2006; Zumbrunn et al., 2011. Five contributing experts in this study reviewed all items on their relevance to estimate self-regulated learning as a relatively steady personal. The CFA result somewhat supports the construct validity scale because the model postulated by the theory is compatible with the acceptable data. Sub-scale correlates significantly, showing that the sixth aspect is related to the same self-regulated learning construct. Planning, monitoring, controlling, and evaluating aspects are closely related, viz. relatively high correlation among the three aspects. Because the three aspects also should represent three phases of the independent learning process (for instance, Cleary & Zimmerman, 2004; Ertmer & Newby, 1996; Zimmerman, 2006), the outcome back up the validity concept model. The SRL element is relative and very consistent over time, indicating that the SRL questionnaire can be used to assess a student's SRL.

SRL questionnaire designed in this research, therefore, can be used to measure students' SRL in the framework of SRL and also complete the previous SRL questionnaires that already have been developed before, for instance, Fontana et al., (2015)developed an SRL questionnaire to measure SRL behaviour in the workplace, Li et al., (2020) developed an SRL questionnaire to measure temporal dynamics of students' SRL behaviors, Pintrich et al., (1993) developed SRL questionnaire to measure motivation in employing learning strategy as one of SRL's elements, monitoring; a researcher, Retnawati (2016b) designed an SRL questionnaire to assess students of Mathematics education program, and research by Zimmerman and Martinez-Pons (1988) developed 14 models of students' SRL strategies in learning activities. This SRL questionnaire is considerably needed because STEM education assesses not only formal skills such as science skills, mathematical literacy, computational thinking, but also information skills such as self-regulated learning (Morris et al., 2019).

Conclusion

According to the result and discussion, the SRL questionnaire developed under this study can be a very reliable instrument for measuring students' SRL as a rather consistent feature. Furthermore, the product was found to fulfill its content and construct validity. The SRL questionnaire includes 14 items with aspects of planning and monitoring (4 indicators for each) and controlling and evaluating (3 indicators for each). However, the current study has several limitations that should be addressed in future investigations, such as thoroughly evaluating SRL questionnaire validity and reliability. The research recommends that the correlation of SRL behavior with the actual mathematics learning result be examined to determine the SRL's predictive validity. Future inquiry can also test the SRL behavior of the students with learning outcomes on particular domain behavior.

Recommendation

This study has possibly produced a valid and reliable self-regulated learning questionnaire in mathematics learning in the STEM framework. If more researchers intend to assess the self-regulated learning of elementary school students, high school students, or college students, future researchers could develop the questionnaire by adjusting it to the characteristics of elementary school or college students. Other topics for further research are proving the predictive validity of the SRL questionnaire with a larger sample and investigating the correlation of SRL scores with the actual behavior and higher order thinking skills such as critical and creative thinking skills, problem-solving skills, or computational thinking. The relationship between independent learning behavior in sports, mathematics, science, and academic achievement tends to be different (Cleary & Zimmerman, 2004; English & Kitsantas, 2013) because the correlation of self-regulated learning may differ in any school subject. Research on the development of SRL instruments in other subjects, such as citizenship and social science also needs to be done to see the extent to which the SRL abilities of students and their correlation with abilities in Islamic religious education subjects.

Limitation

There are a number of constraints in this research that can be used to improve future studies, among which are (1) the research subjects were students from the provinces of Central Java, East Java, and the Special Region of Yogyakarta, and the self-regulated learning questionnaire that was generated was confined to students; and (2) the dimension structure of the self-regulated learning questionnaire construct that is examined using the CFA model, providing that the instrument has been appropriately prepared based on the test specification table and through expert judgment item validation. This priority is on determining the validity and reliability of the self-regulated learning questionnaire that was designed.

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Authorship Contribution Statement

Nu'man: Conceptualization, design, data acquisition, data analysis, writing. Retnawati: Critical revision of manuscript, supervision, interpretation, final approval. Sugiman: Editing/reviewing, technical or material support, supervision. Jailani: Editing/reviewing, supervision.

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