Construction and Validation of Self-Assessment Instrument for Students' Mathematics Classroom Learning Behaviour

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Keywords: classroom learning behaviour, scale development, self-assessment, validation

Abstract

A self-assessment instrument helps mathematics teachers to identify students' learning behaviour and intervene with appropriate instructional design for engaged and meaningful learning in a mathematics class. This study, thus, aims to design, develop, and validate a self-assessment instrument in mathematics classroom learning behaviour for secondary-level students. This study comprises four systematic levels of instrument development and validation processes. Firstly, it begins with a review of different theories and related literature for formulating the relevant assessment domains of the instrument. Secondly, it continues with tool design and item development processes based on the pre-determined domains. The third level involves the draft reviewing process by experts and pre-testing of the draft with a sample of 540 secondary level students. The last stage includes testing and verification of the draft using different statistical tools. Thus, this study establishes a verified students' mathematics classroom learning behaviour self-assessment instrument by completing a systematic process of tool construction.

Introduction

Student learning behaviours are the actions or reactions of the learner during classroom instruction. Classroom learning behaviour is manifested in students' actions and reactions to the subject matters taught in the classroom. Classroom learning behaviours in the self-assessment instrument is conceptualized as the person's activity or action that can be measured and observed (Bicard et al., 2012). Student behaviour inside the classroom is one of the major determinants for their learning outcomes (Ning & Downing, 2010). Student classroom behaviour or classroom practice can play a crucial role in bridging the actual problem from school practice to their everyday life (Passarella, 2022) connected to learning and increase their academic performance (Tan et al., 2019). Student classroom learning behaviour are the manifestation of their social condition, cultural background, and prevailing classroom condition (Bicard et al., 2012; Ning & Downing, 2010). Classroom learning behaviour is directly related to the achievement of the students in different subjects (Tan et al., 2019). The desired behaviours such as obedience, politeness, punctuality, attentiveness in class, listening to teachers, etc., help the teacher deliver effective classroom instruction (Mahvar et al., 2018) and contribute to the learner attain higher achievement in their subject of study (Ning & Downing, 2010). On the other hand, problem behaviours such as teasing, talking unnecessarily in class, coming late to class, being over-talkative, rebuttal to teachers' requests, absenteeism, etc., hamper the students and teachers in the classroom instruction and their performance (Bicard et al., 2012; Mahvar et al., 2018). Since learning behaviour is observable and measurable, it can be determined using a well-constructed tool (Bicard et al., 2012). Student classroom learning behaviours can be measured by using two types of tools: self-assessment tools and assessment tools rated by others. A self-assessment tool can be used to estimate the correct responses in mathematics learning as well as the other disciplines (Andrade, 2019). It provides immediate feedback to the student on their learning behaviours, which can help to promote student engagement and improve learning outcomes (Zekarias, 2023)

The nature of mathematics requires a higher level of abstract reasoning which is not easy to understand for every student (Boaler, 2016). Thus, it is often considered as a difficult subject by both students and teachers equally (Alcock & Simpson, 2019). So, a question regarding learning mathematics likely arises: Why is mathematics often viewed as a difficult subject? It cannot be answered easily in a single sentence; there are many factors that affect mathematics learning. Of them, the students' mathematics classroom learning behaviours have been found to be strong predictors of mathematics achievement (Cleary & Chen, 2009). Student learning behaviours can impact their ability to self-regulate their learning in mathematics (Zimmerman, 2000), so it is crucial for a successful teacher to have knowledge about students’ classroom learning behaviour. Knowledge about the behaviour constructs allows the teacher to tailor their instructional strategies and classroom management techniques to meet the needs of their students (Boaler, 2016).

A successful teacher can identify areas where students may be struggling or disengaged by observing and analysing students' behaviour and can adjust their teaching methods accordingly (Miller & Schunk, 2019). In addition, understanding student learning behaviour also helps teachers create a positive and supportive classroom environment; through providing emotional support and building positive relationships with students, teachers can help create a classroom culture that fosters student participation and learning (Monteiro et al., 2021). So, a validated tool for measuring students’ mathematics classroom learning behaviours is needed to understand the student learning activities and learning patterns that play a crucial role in their learning outcomes and gain insights into the factors that impact student learning.

The identification of student mathematics classroom learning behaviours helps the teacher to motivate students and promote student engagement through personalized learning by tracking students' proper behaviour to meet the needs of individual students. It also helps to identify the areas of weakness, support evidence-based practices, personalized instruction and promote self-reflection (NCTM, 2018). So, the teacher can better understand the students' learning processes and tailor their instruction for additional support to improve the learning outcomes in a timely manner (Lodge et al., 2018). Hence, the knowledge regarding students’ mathematics classroom learning behaviour helps the teacher to create a proper classroom environment that promotes students’ engagement, emotional support and students' interest for the successful learning of mathematics (Hettinger et al., 2023). It can also help them to design effective instruction that is engaging, relevant, and targeted to the needs of their students, support student learning, and promote achievement in mathematics (Velayutham & Loh, 2016).

The student Mathematics Classroom Learning Behaviour Self-assessment Instrument (MCLBSI) is a tool a student uses to measure their own classroom learning behaviours, which can also be used for research purposes to assess the student learning behaviours in the mathematics classroom. Self-assessment is a process of evaluating one's own activity and behaviour in the learning process (Loon, 2018). Also, it can help the students to focus on specific tasks or learning activities to promote their learning (Heftera et al., 2022). The rating scale of the instrument measures different dimensions of the individual, social and emotional behaviours of the learner (Jieping et al., 2022). The study aims to construct a reliable and valid MCLBSI identifying the relevant classroom learning behaviours that accurately measure student learning of mathematics at the secondary level.

Overview of Scale Development

The scale comprises several steps of scale development. It is a time-consuming, complex, costly and rigorous process that requires unique, complex statistical analyses. However, every scale should be valid as well as reliable, and capable of addressing and improving the problems existing in the present context. We attempt to develop the best scale that can be applied in broader areas of the related disciplines, especially for student classroom learning behaviour. The scale is based on the four major steps of item development. Each step comprises other different stairs and technical works to make it more accurate, relevant as well as rigorous. An outline of the construction and validation process of the instrument has been presented in Figure 1.

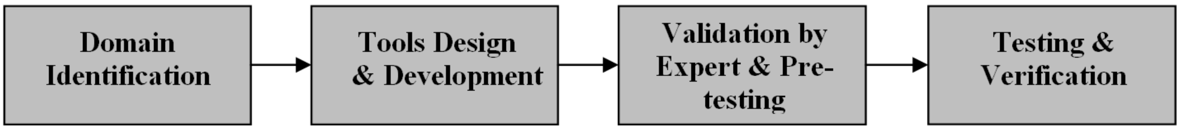

Figure 1. An Outline of Construction and Validation of the Instrument

Theoretical Perspective on Student Learning Behaviour

Learning theory is the best way to attain, retain, recall, and transform the skill, knowledge, and information of the learner. The attainment of Knowledge can be viewed through various theories of learning (Gubermana et al., 2022). It describes the nature of the human mind, the learning process, and human behaviour (Chunk, 2012; Lessani et al., 2016). There are many learning theories in the field of educational psychology, however, generally, all these learning theories fall under the three schools of thought: behaviourism, cognitivism, and constructivism (Lessani et al., 2016).

Knowledge and skills are the products of stimulus and response; strong associations between them can occur in knowledge (Chunk, 2012; Wentzel & Miele, 2016). Behaviourism is the belief that learning depends upon the change of behaviour of an individual. Thus, it emphasizes repeated actions, drills, practice, reinforcement, and the active involvement of an organism to change its behaviours permanently. Behaviourists always stress memorization and rote learning for acquiring knowledge (Lessani et al., 2016). They consider learning as a mechanical process that deals with the stimuli and responses to the environment (Wentzel & Miele, 2016). In this theory, reinforcement plays a significant role for continuing the consistent repetition of the learning tasks (Wentzel & Miele, 2016).

The cognitive learning theory emphasizes the role of mental processes in learning. It involves thinking, perception, memory storage, and recall to complete a learning process (Yilmaz, 2011). This theory is centred on how knowledge can be acquired and focused on the information processing system for meaningful learning (Lessani et al., 2016). Cognitivism focuses on authentic learning, reception learning, reciprocal teaching, scaffolding, and problem-solving (Yilmaz, 2011). It is a progressive restructuring of mental processes rather than the result of physical development (Lessani et al., 2016) and emphasizes individual differences of the learner, environmental experience, and conceptual development of the problem.

Constructivism is based on the foundation that learners themselves construct knowledge or new ideas based on their prior knowledge and experiences (Lessani et al., 2016). Knowledge is developmental, constructed, and socially as well as culturally mediated (Cramer & Castro-Olivo, 2016). It is a meaning-making process or knowledge-construction process through which prior knowledge helps to pose questions, solve problems, and construct new knowledge (Lessani et al., 2016). Also, it is an adaptive activity, so learning depends on the situation and context in which it occurs. Learning is not an innate process but it is well constructed by the learner (Cramer & Castro-Olivo, 2016; Lessani et al., 2016). Students' mathematics learning behaviors may differ in terms of grade level (Wang & Ma, 2020), classroom environment, physical facilities, socio-economic status (Kaur & Kumar, 2018) and cultural factors (Huang et al., 2020). Thus, the instrument measuring students' mathematics learning behavior may differ according to the varied background of the students.

Liang et al. (2020) developed and validated a self-assessment instrument measuring students' mathematics learning behavior comprising four dimensions: attitude toward mathematics, motivation for learning mathematics, learning strategies, and self-regulated learning. Likewise, Tan et al. (2021) constructed and validated a self-assessment instrument for mathematics learning behaviors using exploratory and confirmatory factor analysis consisting of three dimensions: attitude towards mathematics, learning strategies, and academic self-efficacy. Alternately, Zhang et al. (2021) developed a self-assessment instrument to measure middle school students' mathematics learning behavior comprising six dimensions: cognitive strategies, learning motivation, metacognitive strategies, affective strategies, learning environment, and learning outcomes. A self-assessment instrument comprising five dimensions - attitude towards mathematics, motivation for learning mathematics, learning strategies, self-efficacy, and learning outcomes - was developed by Wang et al. (2020) to measure mathematics learning behavior for middle school students. In the same way, Huang, Li & Chen (2020) developed and validated a self-assessment instrument for measuring mathematics learning behavior among university students comprising four dimensions: attitude towards mathematics, learning strategies, self-regulated learning, and academic self-efficacy. The varied dimensions of the self-assessment instruments suggest that the instrument can measure different dimensions of students' mathematics learning behavior depending on the diverse backgrounds of the students and it helps the teacher to better understand students' learning processes to enhance their outcomes. Nonetheless, this study typically comprises six domains extracted from the three schools of thought: behaviorist, cognitivist and constructivist.

The study intends to develop and validate a self-assessment tool that evaluates secondary level student learning behaviour in mathematics classes based on the following research questions:

i) What are the key factors that influence student mathematics learning behaviours?
ii) How can a self-assessment instrument be developed to measure student mathematics classroom learning behaviour accurately?

Methodology

The study applies a quantitative survey research design based on the survey method. It comprises four ascending phases of developing the instrument stated by Lazaro et al. (2019). Each step is designed to make a standardized tool using different processes, tools, and strategies in line with the research questions.

Identification of the Domain/Factor

In this study, the theoretical review of different learning theories and related literature focuses on students’ learning activities and behaviour that often fall under the three schools of thought (Lessani et al., 2016). Against this background, six domains or factors have been identified containing two factors in each thematic area. Considering the contents of mathematics, student classroom practices, and teaching approaches used in the mathematics classroom, an equal weight for each thematic area was assigned. Thus, each factor has been defined shortly with an equal sub-domain or co-factor including their behavioural statement. The factors are stated below separately.

Engagement

Engaged learning is important for meaningful learning and developing students' independence in mathematics. Many students currently rely too much on teachers for their learning, which hinders their progress. Shifting students towards becoming autonomous, self-directed learners can enhance their mathematics learning and achievement. Engaged behaviours in students refer to their level of curiosity, optimism, attention, interest, and excitement during the learning process. These behaviours include exerting effort, concentration, taking initiative, following rules, and positive interaction with peers and teachers (Hattie & Anderman, 2013). Engaged behaviours also encompass the students' motivation to learn and succeed in their studies. The subcategories of the "engagement" factor include imitation, participating in classroom activities, enjoying mathematics class, drill and practice, and engagement in unsocial behaviour.

Motivation

In classroom teaching and learning, motivation refers to students’ readiness to learn or their desire to do some learning activities in the classroom (Wentzel & Miele, 2016). Students have diverse levels of motivation in each activity of different disciplines (Becker et al., 2010). Motivation is an energizer of behaviour that makes the learner do something interesting and enjoyable internally and externally. The subcategories of the factor motivation include activity concentration, liking to do something, attention, curiosity and enthusiasm.

Independence

Students' independence in the classroom means following the student-centred learning approaches that individualize learning and allow learners to take ownership of the process (Meyer et al., 2008). This consists of a common sense of how to manage learning individually and how to face challenges as they occur. The subcategories of the factor independence are individual work, self-direction, exploration, self-practice and autonomy.

Responsiveness

The term 'responsiveness' relates to making a positive and quick reaction to something or someone in the existing situation. It is the immediate act or response of the students in a particular situation in the classroom. It consists of the set of social, cultural, emotional, and academic competencies of the students (Cramer & Castro-Olivo, 2016). Such competencies help the students ascertain new relationships, maintain friendships as well as positive relationships, avoid social isolation, and resolve conflicts. The subcategories of the factor responsiveness include competitiveness, keeping silent, and support to peers, reaction to the teachers and peers, and accountability.

Participation
Participation is frequently associated with the term discussion, which normally denotes a conversation between the teacher and student in the class. Participation also comprises a short interaction between teachers and students or within a small group of students. Classroom participation can also be the consequence of insightful comments, discussions, and interesting results that can foster a high level of energy and passion in classroom learning (Aziz et al., 2018). The subcategories of the factor participation are participation, involvement, non-instructional talking, concentration and talks, and whispers with friends.

Collaboration
Collaborative learning is an emerging specialized classroom design or style of learning. Collaboration is simply a situation in which two or more people work together to create or achieve the same thing. Collaboration can occur in both small and large groups of students, but cooperation denotes mainly a small group of students working together (Johnson & Johnson, 2013). The subcategories of collaboration are group work, group discussion, interaction, cooperativeness and teamwork.

Tool Design and Development

A well designed and developed tool can obtain valid and quality data for research (Metin & Korkman, 2021). In the process of design and development of the tool, the purposes of the test and test specifications are the fundamental aspects (Taherdoost, 2016) that ensure the reliability and validity of the instrument (DeVellis, 2017). The instrument has been constructed and validated under the guidelines followed by Boateng et al. (2018). So, to fully appraise such a construct, it is necessary to incorporate the different dimensions of it and assign items according to the weightage of the construct. The tool MCLBSI was designed for considering the developmental characteristics of the children or their activities as suggested by three learning schools; behaviourism, cognitivism and constructivism. In this course, the learning attributes were divided into six domains or factors: two from each of the three learning camps. All the factors were categorized into five subcategories. So, 30 behavioural items or statements drawing equally from each factor were constructed. The items were constructed containing positive, negative, and neutral statements based on learning attributes in the form of a 5-point Likert-type scale.

Item Construction
The identification of the factors with particular behavioural statements leads to the construction of the items related to student classroom learning behaviour in mathematics. Each item was constructed considering the thematic base accumulating with different levels of cognitive and affective domains of Bloom's revised taxonomy (Anderson & Krathwohl, 2001). Thirty-six items, 6 from each domain, were constructed in the initial stage. The study analyzed participants' language use, sentence structure, and response types. Researchers considered the participants' experiences with classroom phenomena and aimed to use clear and impartial language. Thus the instrument was constructed in a five-scale Likert-type format to provide a simple satisfactory response, rather than a correct response. Each item of

each domain is designed to be simple, short, and straightforward. The instrument was verified by using confirmatory factor analysis to reduce the domain overlapping with another construct. The preliminary instrument was examined by three different experts in the same field.

Validation by Experts

The instrument was validated by 5 teaching-and-research professionals with a minimum of 18 years of work experience in a related field. The guidance and suggestions from the experts were taken from the initial stage of the literature review, selection of a thematic area and domain, designing and development of the instrument, construction of the items, and the use of the verification tools. On completion of the draft of the instrument, it was given to each expert for a thorough review and the draft was revised by incorporating the comments and suggestions given by the experts. Thus, the guidance and suggestions from the experts were taken from an early stage to complete the final version of the instrument with 30 items equally distributed in six factors.

Sample Selection and Pre-testing of the Instrument

In this study, grade IX and X students from Province No. 1 of Nepal were selected as the participants. A sample of 540 students was selected from 12 different public secondary schools. Forty-five students were selected from each school covering a wide range of geographical regions with different demographic backgrounds. Two schools from each of the geographical regions, Mountains, Hills and Terai, were selected representing one school from municipal and the other from rural municipal areas based on the stratified random sampling. Of the 540 students, 391 were female and the remaining 149 were male. The age of the participants ranged from 15 to 19 years. The instrument was translated into Nepali by a Nepali translator and was reviewed by two English-and-Nepali subject experts to ensure the intended meaning of the items was maintained in the translation. Then, the instrument was administered to all the students of grades IX and X in the selected schools after taking approval from the respective school administration. The test was conducted on the last week of December 2021. After completing the test, only 45 test papers from each school were chosen for the study purpose. The instructions and purpose of the test were explained and assurances about the confidentiality of the test result were made to the participant.

Data Analysis

The data were analysed using different test statistics. A confirmatory factor analysis (CFA) was used to verify how well the construct variables correspond to the number of constructs (Li, 2016). It was also used to detect construct validity, especially in particular construct-based instrument development (Dunn & McCray, 2020). It was conducted using the principal axis with varimax rotations on the 30 items of the instrument to investigate the convergent validity as well as the factor structure. The convergent validity of the instrument or the internal consistency was also calculated by using Cronbach's alpha.

Results and Analysis

The factor structure and the relevancy of the items in the specified factors were explored using confirmatory factor analysis. Whether the number of factors is related or not and whether the six-factor model of the instrument fits or not has been explored. This section presents the results of the CFA, validity, and reliability of the construct, adequacy of the sample, suitability of the factors as well as the internal factor structure of the six factors.

Descriptive Statistics

The descriptive statistics of the six factors are presented in Table 1. The mean score of each item and their corresponding standard deviation, and factor-wise mean and standard deviation are given in Table 1.

Table 1. Summary of Mean and Standard Deviation

Items	Construct	Item-wise		Sub-scale	
		M	*SD*	*M*	*SD*
01		4.16	0.80		
02		4.26	0.87		
03	**Engagement**	4.19	0.96	3.66	1.19
05		3.91	0.93		
06		2.80	1.19		
07		4.35	0.83		
08		4.02	0.95		
10	**Motivation**	4.35	0.82	4.22	0.87
11		3.87	0.96		
12		4.54	0.81		
13		3.60	1.24		
14		3.06	1.08		
16	**Independence**	3.69	1.13	3.69	1.06
17		3.78	1.05		
18		4.34	0.84		
19		4.08	1.06		
21		2.57	1.27		
22	**Responsiveness**	4.48	0.80	3.77	1.02
23		3.93	0.98		
24		4.09	0.99		
26		3.85	1.09		
27		4.09	1.96		
28	**Collaboration**	4.04	0.98	3.84	1.25
29		4.58	0.84		
30		2.64	1.41		
32		2.84	1.17		
33		3.93	1.11		
34	**Participation**	3.50	1.24	3.02	1.14
35		3.08	1.09		
36		2.97	1.10		

Testing and Verification of the Instrument

The instrument was tested to verify the appropriateness of the factor structure, validity, reliability, adequacy, and suitability of the factors using different test statistics. The test statistics and the processes used in testing and verifications of the instrument are discussed separately below.

Tests of Dimensionality and Factor Structure

Dimensionality refers to how many traits or attributes a dataset comprises. Dimensionalities, therefore, are the different dimensions or latent variables related to an attribute (Dunn & McCray, 2020). The CFA techniques can best be employed to verify the appropriateness of the dimensions of the factor (Dunn & McCray, 2020). The researchers used a CFA technique to identify the factor dimensionality. CFA estimates the relationship between different underlying constructs and can be used to verify the validity of predetermined factor structures. It can also help identify structural variables and test construct validity (Li, 2016).
The details of the items, domain-wise constructs, and factor loadings have been presented in Table 2.

Table 2. Construct, Items & Factor Loading

Construct		Items	Factor loadings
Engagement	1.	I learn mathematical concepts and items by imitating them as given by the teacher	0.61
	2.	I like to practice the problem related to the exercise with the help of teachers' hints in math class.	0.68
	3.	I enjoy practicing and doing exercises in math class.	0.64
	5.	I learn mathematical concepts, structures and formulae through constant repetitions.	0.62
	6.	It is my experience that we can learn math even without keeping quiet (e.g. playing with objects, sticking a 'tail' to friends' back, throwing objects, destroying objects, instruments, books, etc.).	0.53
Motivation	7.	I feel comfortable and have fun while learning new things in math class.	0.51
	8.	I like to go to the front of the class to share my ideas with peers to solve problems in math class.	0.66
	10.	I listen to and follow the teachers' instructions and suggestions very attentively while practicing mathematical problems.	0.76
	11.	New and challenging mathematical problems make me engaged for a long.	0.70
	12.	I feel excited when I can solve new mathematical problems.	0.71
Independence	13.	I like to practice math alone with my effort.	0.61
	14.	I make several attempts to solve mathematical problems regularly in the classroom without any instruction from others (s).	0.65
	16.	In doing math, I usually try to find out ideas for solving problems through personal initiatives.	0.66
	17.	I am used to solving mathematical problems at home and school.	0.67
	18.	I do mathematical activities best when I am independent.	0.71
Responsiveness	19.	I like practicing and learning math by competing with my peers.	0.72
	21.	I remain silent in math class rather than asking questions.	0.62
	22.	I help my friends and also take help from them when necessary in math class.	0.68
	23.	I react immediately against the teacher or friends if they ignore my issue(s).	0.72
	24.	I think I like to do mathematical activities in the class with full responsibilities.	0.52
Collaboration	26.	I can do mathematical activities best as group work.	0.64
	27.	I feel joyful to take part in classroom discussions in math class.	0.64
	28.	I feel easy to learn some math problems through interaction than other methods (s).	0.63
	29.	I like working in cooperation with my peers in the classroom.	0.72
	30.	I hesitate to work in a team while learning mathematical problems.	0.66
Participation	32.	It is interesting to sit at the back of the classroom and stare out of the window.	0.72
	33.	I learn math with active involvement mainly by doing tasks in the classroom.	0.66
	34.	I talk about non-instructional/private topics in math classes.	0.71
	35.	In math class, I immediately ask the teacher for clarification when I am confused.	0.54
	36.	I also participate with neighboring friends by talking and whispering in class.	0.61

In Table 2, the value of factor loading of the given constructs ranges from 0.51 to 0.76. It lies above the marginal value of 0.50 or higher (Hair et al., 2019). The value of factor loading in each factor above the marginal value signifies that the factors truly measure the six dimensions or six factors model. A value of factor loading greater than 0.5 also suggests a high degree of convergent validity in each construct. This also recommends that the entire construct encompasses higher level convergent validity which means the increment of one factor also enhances to increase the other.

Factor structure is the existence of a correlational relationship between the number of variables to measure a particular construct (Cleare et al., 2018; Dunn & McCray, 2020). Factor structure is also known as the factor model. This study presents a six factors structure model regarding student mathematics classroom learning behaviour. The factor structure of the six-factor model is presented in Figure 2.

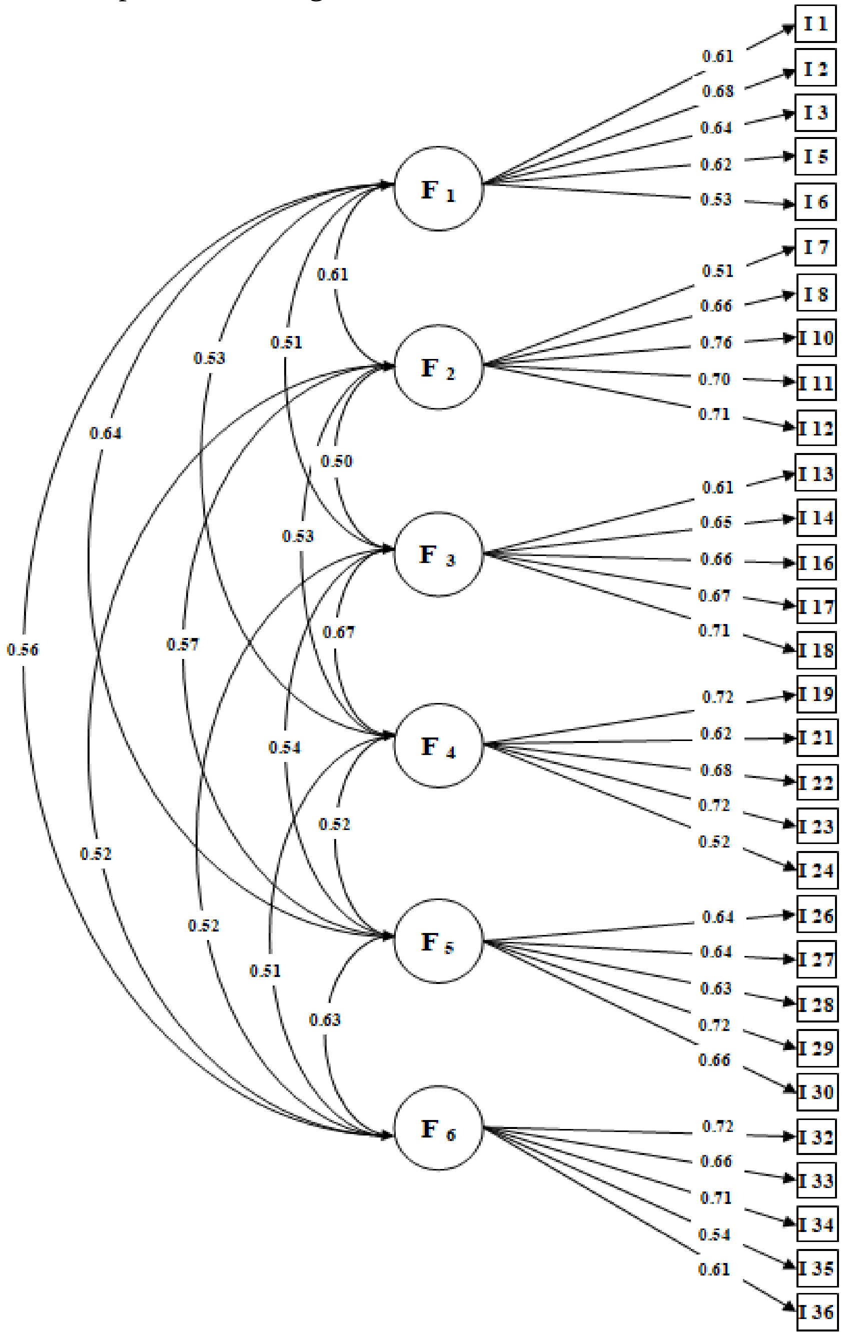

Figure 2. Factors Structure Model (6-Factor Correlated Model)

The six-factor model consisting of 30 items (Figure 2) shows a good fit. A factor loading of 0.4 or more is considered a good measure of an underlying construct being measured (Hair et al., 2019). Similarly, the correlations of 0.5 or higher indicate a strong relationship (Hair et al., 2019; Kline, 2016). In this instrument, the correlation between the factors and the items is also significant or loaded with each factor ranging from 0.51 - 0.76. The higher factor loading indicates an efficient instrument to measure the construct (Dunn & McCray, 2020). Similarly, the correlation coefficient of the factors lies in the range of 0.50 - 0.67. This indicates that the factors contained in the construct are correlated. Therefore, factors loading and correlation of the factors are significant at $N = 540$, $p < 0.001$. So, it is a six-factor correlated model. Thus, it can be confirmed that a six-factor structure model is best fitted to address the student mathematics classroom learning behaviour.

The Kaiser-Meyer-Olkin (KMO) test is an important statistical measure that determines the suitability of factor analysis for the given data set (Shrestha, 2021). The KMO value is more than 0.6 and a significance level for Bartlett's test below 0.05 indicates a significant correlation in the data. Similarly, Bartlett's test of sphericity shows the perfect correlation of all the items with themselves, and also has some level of correlation with the other items (Shrestha, 2021). In Table 3, the KMO value is 0.899, and Bartlett's test of sphericity is significant at 435 degrees of freedom (*df)*. Then both KMO and Bartlett's tests exist for the suitability of the model.

Table 3. Statistics for the Study of the Sample Suitability of the Model

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.899
Bartlett's Test of Sphericity	*Chi-Square*	3764.835
	df	435
	Sig.	0.000

Reliability of the Instrument

Reliability is a measure that produces similar results under similar conditions. It is the degree of consistency demonstrated when a measurement is repeatedly used under the same conditions (Boateng et al., 2018). In this instrument, the internal consistency reliability method Cronbach’s alpha (α) was used. Cronbach's alpha is considered a standard statistical technique to assess the reliability coefficient. Cronbach's alpha is used to assess the reliability, or internal consistency of a set of scale or test items (Jugessur, 2022).). This method is conventionally defined as an item-level approach because it considers each item of a test as a separate test. In this instrument, Cronbach’s alpha was found to be 0.87. The reliability coefficient of the instrument was judged sufficient because an alpha value above 0.60 is considered good (Ab Hamid et al., 2017; Mayers, 2013), which is the minimum requirement, however, 0.80 - 0.95 is considered perfect for the psychometric scales (Nunnally, 1978). In Table 3, the range of Cronbach's alpha (α) is in the range of 0.826 - 0.902. This indicates the reliability of the instrument falls within the preferred range (Jugessur, 2022).

Table 4. Cronbach's Alpha Reliability Coefficient

Construct	Items	Alpha(α)
Engagement	5	0.887
Motivation	5	0.902
Independence	5	0.895
Responsiveness	5	0.826
Collaboration	5	0.858
Participation	5	0.867

Validity of the Instrument

The validity of the instrument ensures that it measures what it exactly intends to measure. Psychometric instruments are always used to find out important inferences concerning people's actions and behaviours. Validity highly concerns the accuracy and consistency of the measuring instrument (Petty et al., 2009). Similarly, the reliability of the instrument conforms to consistency and stability over time (Jugessur, 2022).

According to the American Educational Research Association (2014), the content of the test, its internal structure, and the important features of the test should be measured. In the psychometric type of instrument, it is essential to ensure the content validity, and construct validity related to human action and behaviour in the course of item development and validation process and hence this was established.

Content validity. Regarding the content validity of the instrument, it was minutely observed regarding the relevancy, adequacy, and duplication in both item selection and creation of the domain. The construct and its dimensions were sincerely defined and identified while developing the items by comprehensively reviewing the literature. Also, accuracy and relevancy was considered in formulating the items for the corresponding domain/factors. It was reviewed by a panel of experts and some modifications were made based on their comments and suggestions.

Construct validity. Construct validity is related to how well an instrument measures the construct of a test. It measures the concerned construct of an instrument in association with other domains and real-world criteria. Generally, construct validity can be established by calculating convergent validity and discriminant validity. Convergent validity describe the degree to which a test measures the same construct as other tests that are designed to measure the same or similar constructs, and the extent to which the scores of the test are highly correlated with those of the other tests. (Boateng et al., 2018; Strauss & Smith, 2009). Discriminant validity, on the other hand, does not exist in any relationship to other constructs (Boateng et al., 2018). It can be evaluated by examining the correlations among the trait factors (Strauss & Smith, 2009). The extent to which the six factors are related to each other provides evidence for discriminant validity, which is typically weaker than the correlation between each factor and the items that are intended to measure it. Discriminant validity exists when there is a very low or weak correlation between the constructs (Strauss & Smith, 2009).

Table 5. Convergent and Discriminant Validity

Construct	AVE	E	M	I	R	C	P
Engagement (E)	0.756	**0.869**					
Motivation (M)	0.743	0.716	**0.862**				
Independence (I)	0.714	0.614	0.713	**0.845**			
Responsiveness (R)	0.724	0.702	0.612	0.624	**0.851**		
Collaboration (C)	0.745	0.716	0.662	0.714	0.608	**0.863**	
Participation (P)	0.611	0.695	0.656	0.689	0.616	0.524	**0.834**

Table 5 depicts the square root of average variance extracted (AVE) and the correlation coefficients between the constructs. The diagonal bold figures represent the square root of AVE and the remaining plain figures represent the correlations between constructs. This shows the conditions of convergent and discriminant validity of the instrument. The value of AVE of each respective construct lies between the range of the acceptance level or higher than 0.5 which conforms to the convergent validity (Hair et al., 2019). In this instrument, the AVEs ranged from 0.524 to 0.756. This indicates that all the constructs displayed in Table 5 represent a high degree of convergent validity. Similarly, the discriminant validity of the instrument by using the Fornell and Larcker method (1981) also verifies that the value of AVE is higher than the correlation between the constructs. Thus, the instrument can be accepted based on the convergent and discriminant validity. Similarly, the strong relationship between the two scores on the same factor determines their convergent validity (Hair et al., 2019). Likewise, the poor relationship or no relationship between the two scores on the same factor establishes discriminant validity. This is also known as small factor covariance.

Discussion

The construction of a self-assessment instrument is a rigorous process. There is no fixed process to develop the assessment tool and design so it is also a challenging task itself. Self-assessment can be used to describe a variety of activities in diverse disciplines (Andrade, 2019). Such measurement tools can be developed in two different forms, namely, rating by the informants and rating by other external persons. This self-assessment instrument intends to measure the traits, actions, and behaviours by involving the participant (Tan et al., 2019). Self-assessment instruments have various positive aspects that can benefit both students and teachers. It can promote learners' self-reflection, self-monitoring, increase motivation, and enhance self-regulated learning and thus increase academic performance (Khiat & Vogel, 2022). It can also be helpful to reflect the individual construct and behaviour more effectively.

The items of each factor are constructed before defining the behavioural statements of each factor. The instrument was developed and verified using a systematic process as stated by Boateng et al. (2018), Tan et al. (2019) and Usart Rodríguez et al. (2021). To verify the suitability of the factor structure, accuracy, validity, and reliability of the items, CFA was performed. Likewise, the reliability of the construct was verified by using Cronbach's alpha (Cronbach, 1951). The result of statistical analysis concerning test dimensionality, factor structure, and factor loading was found to be satisfactory. The factor loading or the correlation coefficient between the variables and the factors was found to be correlated (Taber, 2018). The establishment of the six-factor correlated model also verifies that each factor as well as the items related to the corresponding factors is mutually interrelated and best fitted (Dunn & McCray, 2020). It indicates that the model with the best fit has been identified. Similarly, the suitability of the model in terms of factor analysis and adequacy of the sample was observed by employing KMO and Bartlett's Test and was found to be significant. This establishes the appropriate sample size and the model fits factor analysis (Dunn & McCray, 2020). The Cronbach's alpha reliability coefficient of the instrument with the range 0.826 - 0.902 was found sufficient. The range of internal consistency revealed that all six-factors demonstrate perfect internal consistency. This shows that the items included in each factor are likely to have enough weight and are relevant (Lazaro et al., 2018; Mayers, 2013). The convergent and divergent validity was calculated using average variance extracted (AVE) and was found in the range from 0.524 to 0.756. This shows that all the constructs hold a high degree of convergent validity (Mayers, 2013). On the other hand, the discriminant validity was observed by using Fornell and Larcker method and was found verified (Ab Hamid et al., 2017). Thus, the overall results related to statistical measures used in the instrument suggest that the instrument could effectively be used in the purposed area of student mathematics classroom learning behaviour at the secondary level.

Various research studies have been conducted regarding student mathematics learning behaviour measuring tools. Huang et al. (2019) developed and validated a self-evaluation instrument to assess college students' mathematics learning behavior. The instrument comprised 30 items, which were categorized into five subscales: motivation, self-efficacy, metacognitive strategies, self-regulated learning, and mathematics anxiety. The researchers employed exploratory factor analysis to identify the underlying subscales and confirmed the factor structure through confirmatory factor analysis. The internal consistency of the instrument was assessed using Cronbach's alpha, indicating good reliability and validity. The development process of the self-assessment instrument involved iterative steps of item generation, pilot testing, and psychometric analysis. Similarly, Zhang et al. (2021) constructed a self-assessment instrument for middle school students' mathematics learning behavior. The instrument consisted of 28 items and encompassed five factors: motivation, self-efficacy, self-regulated learning, mathematics anxiety, and mathematics achievement. The process of construction and validation followed a similar methodology as Huang et al. (2019), involving item development, pilot testing, and psychometric analysis.

Similarly, Liang et al. (2020) constructed and validated a self-assessment instrument consisting of six domains: motivation, self-efficacy, cognitive strategies, mathematics anxiety, mathematics achievement, and mathematics interest with 38 items for mathematics learning behavior employing the same procedures. The instrument in this research (MCLBSI) was also designed, developed and verified using the same procedures as the above-mentioned instruments, however, this instrument focuses on establishing the direct linkage between the domains/factors and the three different school of thoughts in learning. So, it is expected that the tool may be more efficient for the teacher to develop a more comprehensive and nuanced understanding of how individuals learn and how best to support their learning.

Conclusion

The results of the study show that the self-assessment tool exhibits considerable content validity, construct validity, and reliability. The tool establishes a six-factor structure by the CFA, consisting of engagement, motivation, independence, responsiveness, participation and collaboration. The result of the CFA suggests that the constructs closely correlate. Also, the result of test dimensionality, factor structure, and factor loading was found satisfactory. Thus, the result yielded from different statistical tools such as suitability of the factor analysis, construct validity, and internal consistency of the items confirms that this instrument could yield information regarding the students' responses to questions about the classroom learning activities, learning process, their attitude, feeling and expectations about the overall classroom situation. Not only does this study explore the designing, developing and validating procedures of the self-assessment instrument to measure student mathematics classroom learning behavior but it also provides an effective tool by establishing a connection between different learning theories and the factors that are related to student learning activities which directly influence student learning and achievement in mathematics.

Implications

It is expected that the item development outline for measuring student mathematics classroom learning behaviour based on the thematic area and the creation of a verified instrument itself could be applied to mathematics teaching and learning at the secondary level. Also, creating items and the process undertaken for extensive item development and verification can be applied to other subjects, too. Hence, the findings of this study likely contribute to the development and designing of effective intervention programs for classroom instruction.

Acknowledgments

This work was undertaken with the financial support from the University Grants Commission (UGC), Nepal. We would like to express our appreciation to the students of grades IX and X and school administrators for their help and cooperation while testing the instrument. It was approved by the Faculty of Education, Tribhuvan University on May 4, 2018 [Ref. 1052].

Declaration

The article is part of PhD of first author. We would like to thank UGC, Nepal for the PhD Fellowship and the respondents for their time and responses.

References

Ab Hamid, M. R., Sami, W., & Sidek, M. M. (2017, September). Discriminant validity assessment: Use of Fornell & Larcker criterion versus HTMT criterion. *Journal of Physics: Conference Series*, 890. https://doi.org/10.1088/1742-6596/890/1/012163

Alcock, L., & Simpson, A. (2019). Why is mathematics so difficult for so many? *The Journal of Philosophy of Education, 53*(3), 503-516. https://doi.org/10.1111/1467-9752.12341

American Educational Research Association, American Psychological Association, & National Council on Measurement in Education (Eds.). (2014). *Standards for educational and psychological testing*. American Educational Research Association.

Anderson, L., & Krathwohl, D. A. (2001). *Taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.

Andrade, H. L. (2019). A critical review of research on student self-assessment. *Frontiers in Education. 4*:87. https://doi.org/10.3389/feduc.2019.00087

Aziz, F., Uzma Quraishi, U., & Kazi, A. S. (2018). Factors behind classroom participation of secondary school students. *Universal Journal of Educational Research, 6*(2), 211 –217. https://doi.org/10.13189/ujer.2018.060201

Becker, M., McElvany, N., & Kortenbruck, M. (2010). Intrinsic and extrinsic reading motivation as predictors of reading literacy: A longitudinal study. *Journal of Educational Psychology, 102*(4), 773–785. https://doi.org/10.1037/a0020084

Bicard, S. C., Bicard, D. F., & the IRIS Center (2012). *Defining behavior*. Retrieved from http://iris.peabody.vanderbilt.edu/case_studies/ ICS-015.pdf

Boaler, J. (2016). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. John Wiley & Sons.

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioural research: A primer. *Frontier Public Health*, *6*(149), 1–18. https://doi.org/10.3389/fpubh.2018.00149

Chunk, D. H. (2012). *Learning theories: An educational perspective.* (6th Edition). Pearson Education,Inc.

Cleare, S., Gumley, A., Cleare, C. J., & O'Connor, R. C. (2018). An investigation of the factor structure of the self-compassion scale. *Mindfulness*, *9*(2), 618–628. https://doi.org/10.1007/s12671-017-0803-1

Cleary, T. J., & Chen, P. P. (2009). Self-regulation, motivation, and math achievement in middle school: Variations across grade level and math context. *Journal of School Psychology, 47*(5), 291-314. https://doi.org/10.1016/j.jsp.2009.05.001

Cramer, K. M., & Castro-Olivo, S. (2016). Effects of a culturally adapted social-emotional learning intervention program on students' mental health. *Contemporary School Psychology*, *20*(2), 118–129. https://doi.org/10.1007/s40688-015-0074-3

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297-324.

DeVellis, R. F. (2017). *Scale development: Theory and applications* (4th Edition.). Sage Publication.

Dunn, K. J. & McCray, G. (2020). The place of the bifactor model in confirmatory factor analysis investigations into construct dimensionality in language testing. *Frontiers in Psychology. 11*, 1357. https://doi.org/10.3389/fpsyg.2020.01357

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39-50.

Gubermana, R., Grobgelda, E., Rozanova, Y. M., & Erakya, A. (2022). Is the bridge really so far away? Elementary mathematics teachers' competencies to implement neuroscience theory into their teaching practices. *International Journal of Innovation in Science and Mathematics Education*, *30*(1), 45–56. https://doi.org/10.30722/IJISME.30.01.004

Hair, J. F., Black, W. C., Babin B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th Edition). Cengage.

Hattie, J., & Anderman, E. M. (2013). *International guide to student achievement*. Routledge.

Heftera, M. H., Hofeb, R., & Bertholda, K. (2022). Effects of a digital math training intervention on self-efficacy: Can clipart explainers support learners? *International Journal of Innovation in Science and Mathematics Education, 30*(4), 29–41. https://doi.org/10.30722/IJISME.30.04.003

Hettinger, K., Lazarides, R., & Schiefele, U. (2023). Motivational climate in mathematics classrooms: teacher self-efficacy for student engagement, student- and teacher-reported emotional support and student interest. *ZDM Mathematics Education 55*, 413–426. https://doi.org/10.1007/s11858-022-01430-x

Huang, R., Chen, Z., & Zhao, Y. (2020). The influence of cultural factors and socioeconomic status on mathematics learning behaviour: A study of Taiwanese high school students. *International Journal of Science and Mathematics Education, 18*(8), 1519–1534. https://doi.org/10.1007/s10763-019-10036-2

Huang, R., Li, J., & Chen, Z. (2019). Construction and validation of self-assessment instrument for university students' mathematics learning behaviour. *Mathematics Education Research, 24*(1), 63–72. https://doi.org/10.1007/s13394-019-00249-8

Jieping, S., Cheung, A. C., Zhang, Q., & Tam, W. W. (2022). Development and validation of a social-emotional skills scale: Evidence of its reliability and validity in China, *International Journal of Educational Research*, *114*, 102007. https://doi.org/10.1016/j.ijer.2022.102007.

Johnson, D. W., & Johnson, R. T. (2013). The impact of cooperative, competitive, and individualistic learning environments on achievement. In Hattie, J., & Anderman, E.(Eds.), *International handbook of student achievement.* (pp. 372–374). Routledge.

Jugessur, Y. (2022). Reliability and internal consistency of data: significance of calculating Cronbach's Alpha Coefficient in educational research. *International Journal of Humanities and Social Science Invention 11*(4), 09-14. https://doi.org/10.35629/7722-1104030914

Kaur, H., & Kumar, V. (2018). Factors affecting students' mathematics achievement in India: A study using hierarchical linear modelling. *International Journal of Science and Mathematics Education, 16*(4), 671–690. https://doi.org/10.1007/s10763-016-9758-0

Khiat, H., & Vogel, S. (2022). A self-regulated learning management system: Enhancing performance, motivation and reflection in learning. *Journal of University Teaching & Learning Practice, 19*(2), 43–59. https://doi.org/10.53761/1.19.2.4

Kline, R. B. (2016). *Principles and practice of structural equation modeling*. Guilford publications.

Lazaro, J. L., Usart, M., & Gisbert, M. (2019). Assessing teacher digital competence: The construction of an instrument for measuring the knowledge of pre-service teachers. *Journal of New Approaches in Educational Research*, *8*(1), 73–78. https://doi.org/10.7821/naer.2019.1.370

Lessani, A., Md. Suraya, A., Bakar, K. A., & Khameneh, A. Z. (2016). Comparison of learning theories in mathematics teaching methods. *21 Century Academic Forum, 9*(1), 165–174.

Li, C. H. (2016). Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares. *Behavioural Research Method 48*(3), 936–949. https://doi.org/10.3758/s13428-015-0619-7

Liang, J., Chen, Z., & Zhao, Y. (2020). Development and validation of a self-assessment instrument for mathematics learning behaviours. *Journal of Mathematics Education, 29*(5), 1–12. https://doi.org/10.16387/J.MATHEDU.2020.05.01

Lodge, J. M., Kennedy, G., Lockyer, L, Arguel, A., & Pachman, M. (2018). Understanding difficulties and resulting confusion in learning: An integrative review. *Frontiers in Education, 3*: 49. https://doi.org/10.3389/feduc.2018.00049

Loon, M. (2018). Self-assessment and self-reflection to measure and improve self-regulated learning in the workplace. In: McGrath, S., Mulder, M., Papier, J., Suart, R. (Eds). *Handbookof Vocational Education and Training.* Springer.

Mahvar, T., Ashghali Farahani, M., & Aryankhesal, A. (2018). Conflict management strategies in coping with students' disruptive behaviours in the classroom: Systematized review. *Journal of Advances in Medical Education & Professionalism, 6*(3), 102–114. https://doi.org/10.22100/journalamep.v6i3.743

Mayers, A. (2013). *Introduction to statistics and SPSS inpsychology*. Pearson Education Limited.

Metin, M., & Korkman, N. (2021). A valid and reliable scale development study to determine the problems encountered by teachers in the distance education process. *Journal of Educational Technology & Online Learning, 4*(2), 215–235. https://doi.org/10.31681/jetol.911074

Meyer, B., Haywood, N., Sachdev, D., & Faraday, S. (2008). *Independent learning: Literature review.* Learning and Skills Network.

Miller, A. D., & Schunk, D. H. (2019). *Handbook of child psychology and developmental science: Socio-emotional processes Vol. 3*. John Wiley & Sons.

Monteiro, V., Carvalho, C., & Santos, N. N. (2021). Creating a supportive classroom environment through effective feedback: Effects on students' school identification and behavioural engagement. *Frontiers in Education, 6*:661736. https://doi.org/10.3389/feduc.2021.661736

National Council of Teachers of Mathematics. (2018). *Catalyzing change in high school mathematics : initiating critical conversations*. National Council of Teachers of Mathematics.

Ning, H. K., & Downing, K. (2010). Connections between learning experience, study behaviour and academic performance: a longitudinal study. *Educational Research, 52*(4), 457–468. https://doi.org/10.1080/00131881.2010.514381

Nunnally, J. C. (1978). *Psychometric theory*. McGraw-Hill.

Passarella, S. (2022). Real contexts in problem-posing: An exploratory study of students' creativity. *International Journal of Innovation in Science and Mathematics Education, 30*(1), 15–29. https://doi.org/10.30722/IJISME.30.01.002

Petty, R. E., Briñol, P., Loersch, C., & McCaslin, M. J. (2009). The need for cognition. In M. R. Leary & R. H. Hoyle (Eds.), *Handbook of individual differences in social behaviour* (pp. 318–329). Guilford Press.

Shrestha, N. (2021). Factor analysis as a tool for survey analysis. *American Journal of Applied Mathematics and Statistics, 9* (1), 4–11. https://doi.org/10.12691/ajams-9-1-2

Strauss, M. E., & Smith, G. T. (2009). Construct validity: advances in theory and methodology. *Annual Review of Clinical Psychology, 27*(5), 1–25. https://doi.org/10.1146/annurev.clinpsy.032408.153639

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education, 48*(1),1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Taherdoost, H. (2016). How to design and create an effective survey/questionnaire; A step-by-step guide. *International Journal of Academic Research in Management, 5*(4), 37–41. https://doi.org/10.7813/2075-4124.2016/5-4/B.6

Tan, H., Chen, Z., & Zhao, Y. (2021). Development and validation of a self-assessment instrument for mathematics learning behaviours. *Studies in Mathematics Education, 2*(1), 1–13. https://doi.org/10.1080/24739871.2021.1878697

Tan, L. K., Loh, G. H., & Zhang, P. C. (2019). Development and validation of the self-regulated learning behaviour scale (SRLBS) to measure impact of student self-assessment. *Asian Journal of the Scholarship of Teaching and Learning, 9*(2), 167–185. https://doi.org/10.20448/journal.529.2019.92.167.185

Usart Rodríguez, M., Lázaro Cantabrana, J. L., & Gisbert Cervera, M. (2021). Validation of a tool for self-evaluating teacher digital competence. *Education, 24*(1), 353–373, https://doi.org/10.5944/educXX1.27080

Velayutham, S., & Loh, Y. F. (2016). Mathematics classroom environment and mathematics achievement: A study on the perceptions of students in Singapore. *International Journal of Science and Mathematics Education*, *14*(4), 719-737.

Wang, X., & Ma, X. (2020). Grade-level differences in mathematics learning behaviour: A study of Chinese primary and secondary school students. *Education Sciences*, *10*(12), 360. https://doi.org/10.3390/educsci10120360

Wang, Y., Guo, J., & Liu, J. (2019). Development and validation of a self-assessment instrument for middle school students'. *Journal of Mathematics Education, 28*(6), 1-10. https://doi.org/10.16387/J.MATHEDU.2019.06.01

Wentzel, K. R., & Miele, D. B. (Eds.). (2016). *Handbook of motivation at school* (2nd ed.). Routledge. https://doi.org/10.4324/9781315773384

Yilmaz, K. (2011). The cognitive perspective on learning: Its theoretical underpinnings and implications for classroom practices. *Journal of Educational Strategies, Issues, and Ideas, 84*(5), 204–212. https://doi.org/10.1080/00098655.2011.568989

Zekarias, A. P. (2023). Contributions and controversies of self-assessment to the development of writing skill. *Journal of Research in Instructional, 3*(1), 13– 30. https://doi.org/10.30862/jri.v3i1.94

Zhang, J., Chen, Z., & Zhao, Y. (2021). Development and validation of a self-assessment instrument for middle school students' mathematics learning behaviour. *Research in Mathematics Education, 21*(2), 187–199. https://doi.org/10.1080/14794802.2021.1889690

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). Academic Press.