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Validity of instrument to measure mathematics teachers' perceptions towards 4C skills in problem solving

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ABSTRACT

In the contemporary education 4.0 landscape, teachers are urged to prioritize the communication, collaboration, critical thinking, and creativity (4C) skills during teaching and learning, recognized as crucial skills for the 4.0 industrial revolution (I.R 4.0). This research aimed to develop and validate an instrument assessing mathematics teachers' perceptions of the 4C skills through problem-solving teaching method. Employing a quantitative research design, the study utilized a questionnaire for data collection, involving four experts and 120 participants. Descriptive analysis using Cronbach's alpha and exploratory factor analysis (EFA) revealed a high reliability (Cronbach's alpha=0.934) and factor eigenvalue exceeding 1. The KMO values (Kaiser–Meyer–Olkin) for each construct were 0.50, and Bartlett's Test was significant (<0.5). Additionally, each item demonstrated a factor loading value above 0.50 and a variance percentage of ≥60%. The instrument comprised four sub-constructs and 16 fitting items. In summary, the study affirms the utility of this instrument in investigating mathematics teachers' perceptions of 4C skills through problem-solving teaching methods.

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1. INTRODUCTION

The fourth industrial revolution denotes the contemporary trends in automation and data exchange within manufacturing and related sectors. This transformative era has significantly altered how humans work and live, with expectations of continued impact on the future of industry and society, surpassing the changes witnessed in previous revolutionary periods [1]. Consequently, various disciplines, including education, have adjusted their focus to meet the demands of Industry 4.0 [2].

Education plays a crucial role in preparing the workforce for this era, emphasizing the need for individuals to acquire skills in digital literacy, coding, data analysis, and knowledge of emerging technologies like Internet of Things (IoT) and artificial intelligence (AI) [3]. Furthermore, fostering soft skills such as creativity, problem-solving, and critical thinking is deemed essential, reflecting the evolving requirements of Industry 4.0 [4]. Lifelong learning becomes imperative to keep pace with the rapid technological advancements, necessitating an evolution in the national education system to cultivate human resources aligned with the demands of Industry 4.0 [5].

The national education system should concentrate on cultivating essential skills in students for the industry 4.0 era. The heightened demand for creativity, communication, critical thinking, and collaboration

(4C) in the future workforce underscores the importance of these skills [6]. Teachers play a pivotal role in preparing students for this era, functioning as learning facilitators who engage students in activities that stimulate critical and creative thinking [7].

In mathematics education, teachers play a crucial role in promoting students' holistic development by focusing on 4C skills through problem-solving tasks [8]. These tasks serve as catalysts, inspiring students to generate diverse ideas applicable to real-world situations. Through open-ended problems and real-world projects, teachers encourage the practical application of mathematical knowledge, motivating students to move beyond routine thinking and fostering a dynamic approach to problem-solving [9].

By integrating problem-solving tasks, mathematics teachers go beyond imparting numerical knowledge, fostering a well-rounded skill set [10]. Group problem-solving emphasizes collaboration and communication, encouraging collective work and idea exchange. The creative and critical thinking demanded in these tasks deepen students' understanding of mathematical principles, preparing them for a future where such multifaceted skills are essential for success in diverse academic and professional pursuits [11].

In conclusion, teachers need to adapt their teaching techniques to foster the acquisition of vital 4C skills. To address gaps in teacher training and support and guide future professional development, it is essential to measure the perceptions of mathematics teachers' perceptions towards 4C skills in problem solving. The development and validation of an instrument for this purpose can serve as a valuable tool for researchers and teachers, facilitating data collection on how teachers perceive the efficacy of these teaching methods in promoting 4C skills and their implementation in classrooms.

2. LITERATURE REVIEW

The challenges posed by Industrial Revolution 4.0 highlight the crucial role of the education system in cultivating skills like 4C to empower the upcoming generation [12]. Addressing these challenges requires teachers to adapt their methods, especially in mathematics education, ensuring the integration of 4C skills in problem-solving activities [13], [14]. Problem-solving emerges as a potent method for skill development, fostering the generation of diverse ideas and innovations [14].

In the context of implementation, the 21st Century Learning Model framework serves as a guiding principle for effective teaching by emphasizing the development of 4C skills through problem solving [15]. This comprehensive approach recognizes the importance of students applying knowledge and skills in real-world contexts to succeed in the 21st century, particularly in the digital age and the Industrial Revolution 4.0 era [16]. Teachers widely utilize this framework to implement methods fostering 21st-century skills, as evidenced by studies such as those by Muhammad *et al.* [16] and Huang and Iksan [17], especially in mathematics education.

The framework encourages the use of technology and the inclusion of real-world problem-solving assignments, aiding students in cultivating essential critical thinking and problem-solving abilities required in the context of the 4.0 era [18]. Through the incorporation of authentic problems and projects, the framework enables students to apply their knowledge, equipping them for the evolving demands of the technological landscape. This approach facilitates the enhancement of students' critical thinking and problem-solving skills, positioning them to meet the challenges of the 4.0 era [19].

After reviewing various prior studies, the researchers observed a scarcity of investigations delving into the aspects of 4C skills specifically within mathematics education [20]–[22]. This scarcity is attributed to earlier studies concentrating more on appraising the preparedness and limitations of teachers regarding the integration of 4C skills in different educational settings [23]–[27]. Therefore, the researchers posit a necessity for an instrument to assess the perception of mathematics teachers regarding 4C skills through problem-solving instructional approaches.

In conclusion, this research aims to address existing gaps by developing and validating an instrument to gauge mathematics teachers' on 4C skills through problem solving instructional approaches. The intention is to pinpoint areas where teachers might require extra support or training, facilitating the successful implementation of these methods in classrooms and enhancing overall student learning outcomes. To that end, students can acquire the necessary skills required in the era of 4.0.

3. METHOD

The study utilized the survey method, a suitable approach for collecting quantitative data from a large population. This method is commonly employed to gather information on diverse subjects, including attitudes, beliefs, and behaviors [28]. This study included a sample of 120 mathematics teachers, chosen based on a loading factor value of 0.50 [29].

The study utilizes an instrument to measure variables, emphasizing the importance of a well-designed questionnaire for effective data collection. The instrument in this study is developed based on the 21st Century Learning Model framework [30], depicted in Figure 1. The instrument comprises 21 items designed to assess the 4C skills within the context of problem-solving, as outlined in Table 1. The specifics of each domain's items are provided in Table 2.

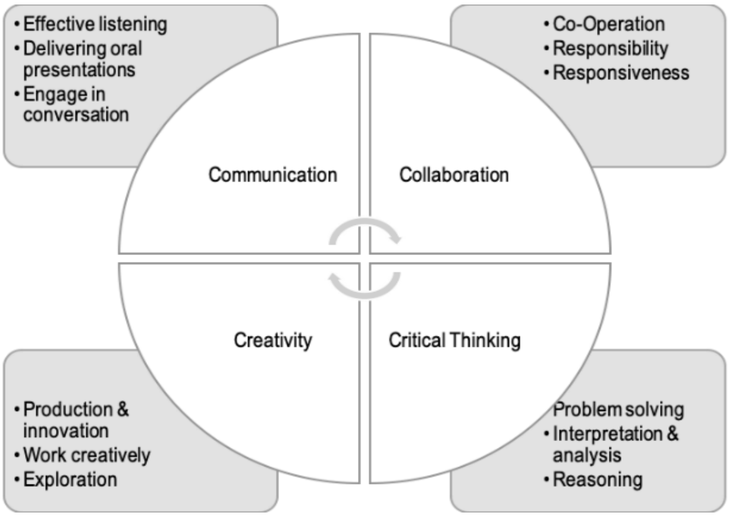

Figure 1. The 4Cs 21st century skills

Table 1. Information about the questionnaire items

Part	Construct/Sub-construct	Numbers of items
Part A	Demography	
Part B	4C skills through problem solving	
	Communication	5
	Collaboration	5
	Critical thinking	6
	Creativity	5
	Total	21

Table 2. Details of questionnaire items categorized by construct

Sub-construct	Item	
Communication	Provide an opportunity for students to re-explain the questions using their own words.	C1
	Encourage students to discuss problem-solving strategies in groups.	C2
	Encourage students to share ideas in group activities.	C3
	Allow students to explain the problem-solving strategy that has been chosen.	C4
	Encourage students to give feedback on other problem-solving group strategies.	C5
Collaboration	Conduct group activities involving students of various abilities.	Colla1
	Guide students to be responsible for the tasks given in the group.	Colla2
	Encourage each group member to appreciate other friends' contributions and ideas.	Colla3
	Involve all students in groups through the division of tasks according to the students' capabilities.	Colla4
	Guide students to accept and respect other people's problem-solving strategies.	Colla5
Critical Thinking	Encourage students to explore various problem-solving alternatives.	Ct1
	Provide space for students to think about various problem-solving strategies.	Ct2
	Using the memorization method of keywords and related formulas.	Ct3
	Using Polya Model only to solve problem-solving questions.	Ct4
	Encourage students to explore various learning resources (For example: using ICT)	Ct5
	Conduct various hands-on activities to provide students with a learning experience.	Ct6
Creativity	Integrate ICT with appropriate teaching methods.	Cr1
	Use various methods proposed in 21st-century learning (for example, flipped classroom)	Cr2
	Use various problem-solving strategies to improve students' understanding (for example, using the Bar Model).	Cr3
	Diversify the forms of questions that can generate the idea to solve the problem-solving questions.	Cr4
	Create various learning materials according to the abilities of the students.	Cr5

The instrument used a 5-point Likert scale to evaluate the variables in this investigation. The data from this pilot study was analyzed using IBM SPSS Version 20. Face, content, and construct validity were established to guarantee that the instrument sufficiently covers the concerns under inquiry and that the acquired data accurately represent the study's results [31].

To carry out the face and content validity processes, four experts specializing in assessment and evaluation, mathematics education, curriculum, and Malay studies were enlisted. To determine the content validity index, a study should involve at least three experts [32]. This expert panel determined whether i) the proposed items were appropriate; ii) the quantity of items was sufficient; iii) proper language, sentence structure, and terminology were used; and iv) the 5-point scale could successfully evaluate the items.

Following the expert evaluation, 4 items were eliminated from the sub-constructs of communication, cooperation, critical thinking, and creativity. Consequently, only 21 out of the initial 25 items in the questionnaire remained, as illustrated in Table 1. To assess the construct validity of the instrument based on data from the pilot study, the researcher employed exploratory factor analysis (EFA).

This procedure aimed to validate each sub-construct item for measuring the designated construct [29]. The analysis considered three crucial factors: sampling adequacy, correlation matrix, and sample size. Various tests for sampling adequacy, detailed in Table 3, were conducted to scrutinize the adequacy of the sample and the relevance of the data [33].

To ensure the clarity of each item within the sub-constructs, principal component analysis (PCA) with varimax rotation was utilized [29]. Parallel analysis methods were also applied to identify which elements should be retained or discarded [34]. Conversely, the eigenvalue was employed to ascertain the necessary number of factors in the instrument.

Once construct validity was confirmed, the researcher proceeded to evaluate the instrument's reliability. The objective was to measure the internal consistency of the instrument, a statistical gauge reflecting the correlation among all its components. A significant alpha value indicates strong item correlation, signifying a high level of internal consistency [29]. Subsequently, the Cronbach's Alpha value was computed and compared to the benchmarks recommended by Bond and Fox [35]. Items with scores below 0.5 were considered to have low internal consistency, while those scoring between 0.8 and 1.0 were deemed highly reliable.

4. RESULTS

PCA was utilized along with Varimax rotation to examine the correlation among items and assess the adequacy of sampling. The Kaiser-Mayer Olkin (KMO) produced a value of 0.783, indicating that the sample measurements were sufficient for determining the factor structure. The Bartlett sphericity test, which measures the intensity of the relationship between variables, confirmed the appropriateness of the factor analysis. The data generated from the completed procedure is presented in Table 3.

The researcher assessed the correlation values between items and loading factor values to identify suitable items. Items with correlation and factor loading values exceeding 0.50 (>0.50) were retained, while those with lower values were excluded. This process aimed to ensure that each remaining item exhibited a strong correlation coefficient with others. As a result, 5 items were eliminated from the instrument, as indicated in Table 4, which illustrates the number of items removed by construct. Additionally, Table 5 presents the factor loading values for the retained items, resulting in a total of 16 items following the conclusion of the exploratory factor analysis.

After completing the factor analysis, the researcher proceeded with assessing the reliability of the measuring instrument. The calculation of Cronbach's alpha value was performed and compared to the values recommended by Bond and Fox [35]. The 16 remaining items within this instrument collectively exhibit consistency and effectiveness, evident in the Cronbach alpha value of 0.93.

Table 3. The correlation value between items and sampling adequacy

Consideration	Recommended value	Actual values
Correlation between items	±0.50	All items have a correlation value≥0.50
Measures of sampling adequacy		
Kaiser-Mayer Olkin (KMO)	≥0.50	0.783
Bartlett's test of sphericity	<0.05	0.000
Anti–image correlation matrix	≥0.50	0.564–0.898
Communality value	≥0.05	0.533–0.936
Factor loading value	≥0.50	0.501–0.902
Eigenvalue	>1	1.229–8.103
Percentage of variance	≥60%	79.890%
Parallel analysis	Associated eigenvalue>eigenvalue from random uncorrelated data	4 factors

Table 4. Distribution of items after factor analysis

Part	Construct/Sub-construct	Numbers of items	The number of items dropped
Part A	Demography	5	0
Part B	4C skills through problem solving		
	Communication	5	0
	Collaboration	5	0
	Critical Thinking	6	3
	Creativity	5	2
	Total	21	5

Table 5. Factor loading values

Item	Factor loading value (N=120)				Communalities
	Factor 1	Factor 2	Factor 3	Factor 4	
Colla2	.896				.903
Colla1	.874				.842
Colla3	.766				.693
Colla4	.677				.764
Colla5	.614				.777
C5		.519			.784
C2		.902			.926
C3		.893			.936
C1		.892			.868
C4		.790			.819
Ct2			.819		.802
Ct6			.796		.800
Ct1			.739		.738
Cr1				.509	.822
Cr2				.872	.776
Cr3				.501	.533

5. DISCUSSION

The outcomes of the EFA and the Cronbach's alpha value underscore the heightened validity and reliability of the instrument assessing mathematics teachers' perceptions towards 4C skills through problem solving teaching methods. Both methodologies contribute significantly to enhancing the instrument's overall validity and reliability. The EFA method plays a crucial role in bolstering validity by i) uncovering the inherent structure of a variable set; ii) establishing interrelationships between variables; iii) identifying factor loadings; and iv) pinpointing any item lacking substantial loading on any factor [36].

Beavers *et al*. [37] asserted that the EFA method serves as a valuable tool for assessing instrument validity by discerning the underlying factors or dimensions elucidating relationships within a variable set. Consequently, employing this method ensures that the instrument accurately captures the intended construct. Moreover, following the EFA process, 5 items were excluded due to their failure to meet the criteria for item acceptance, particularly when their correlation and factor loading values were below 0.50.

Factor loadings denote the correlation between each item and a specific factor, with values approaching 1 indicating a robust relationship and values nearing 0 signifying a weaker connection [38]. By retaining items with factor loadings surpassing 0.5, the researcher ensures that the retained items are more likely to gauge the underlying factor, thereby enhancing the interpretability and accuracy of the analysis results, as items weakly associated with the factor might introduce bias into the outcomes [39]. Additionally, the results of the exploratory factor analysis revealed that the instrument's construct is delineated by four factors: communication, collaboration, critical thinking, and creativity, each generating a distinct factor.

This underscores the appropriateness of these four factors for evaluating the perceptions of mathematics teachers concerning the 4C skills through problem solving. Ruscio and Roche [40] and Izquierdo *et al*. [41] advocate that an instrument attains a high level of validity when the number of factors generated aligns with the initial number of factors, reinforcing the instrument's capacity to measure the construct with a high degree of validity. Furthermore, the number of items allocated to each construct is sufficient to assess the subconstructs of communication (5 items), collaboration (5 items), critical thinking (3 items), and creativity (3 items).

This adheres to the criterion commonly employed by Bro and Smilde [42], which recommends a minimum of 3 items per construct or factor in questionnaire-based studies using EFA to ensure accurate measurement. Yusoff [43] supports this perspective, highlighting that having a minimum of 3 items per construct enhances the factor's reliability by providing more comprehensive information, resulting in more stable and consistent outcomes. With fewer than 3 items per construct, obtaining a unique estimate of factor loadings becomes challenging, hindering the interpretation of the factor structure.

Additionally, the 16 retained items in this instrument exhibit an excellent and effective level of consistency. According to Bond and Fox [35], instruments with Cronbach's alpha scores ranging from 0.8 to 1 demonstrate high reliability and consistency. This implies that the questionnaire possesses high validity and reliability. This standpoint is reinforced by Trizano and Alvarado [44], where an alpha value of 0.7 or higher is considered indicative of good internal consistency. Thus, the recorded value of 0.93 signifies strong internal consistency, affirming that the instrument's items consistently measure the same construct.

6. CONCLUSION

The conducted exploratory factor analysis (EFA) and reliability test in this study aim to ensure the practical applicability of the developed instruments. It is imperative to adjust the existing instruments to guarantee that all remaining constructs and items in the questionnaire adhere to the minimum requirements. According to the factor analysis, this instrument successfully generates four factors: communication, collaboration, critical thinking, and creativity, with the number of generated factors matching the original instrument's constructs. All retained items within each factor meet the minimum requirement for item acceptance, specifically a factor loading value of at least 0.50. The instrument demonstrates high reliability, signifying its suitability for real-world studies. for future research, the researchers recommend conducting a confirmatory factor analysis (CFA) to formulate a structural equation modeling (SEM) model aligned with the study data. In conclusion, this study has effectively validated the perceptions of mathematics teachers regarding 4C skills through problem-solving teaching methods involving communication skills, collaboration, critical thinking, and creativity, making it applicable for practical use in studies.

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