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Development and Validation of the STEM-DT Instrument: A Confirmatory Factor Analysis for Assessing Readiness STEM and Design Thinking Competencies

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Abstract **– This research aims to develop and assess the STEM-DT instrument's validity, reliability, and external validity through small-scale implementation. The development process entailed three stages: literature review, expert validation, and small-scale trials. The research sample comprised 603 current and prospective teachers in a teacher professional program. The research findings indicated that the STEM-DT instrument effectively captured three key dimensions: identification and development of learning needs, innovation and collaboration in learning, and implementation and evaluation of integrated learning. These dimensions were supported by both exploratory and confirmatory factor analyses, demonstrating strong construct validity and an overall good model fit. The external validity assessment revealed that the instrument was able to differentiate STEM-DT abilities across diverse demographic groups. Gender differences were observed, with women showing a higher proficiency in STEM-DT abilities than men.**

Additionally, the study found that STEM-DT abilities varied with age, with older participants exhibiting stronger competencies than their younger counterparts. These findings underscore the instrument's robustness in measuring STEM-DT capabilities and its sensitivity to demographic variations, highlighting its potential utility in diverse educational contexts.

Keywords **– STEM, CSTEM-DT, EFA, CFA, design thinking.**

1. Introduction

The adoption of STEM (Science, Technology, Engineering, and Mathematics) learning is widely recommended, including in Indonesia [31] to improve students' academic abilities [19] and 21st-century competencies. The consistency of teachers in applying the STEM approach in learning is a crucial aspect of its effective implementation [12], as it can impact learners positively. Compared to the popular STEM approach, design thinking (DT) is a newer approach that significantly enhances learners' engagement with various disciplines [44]. This is because DT allows learners to face real-world situations and solve problems [27]. Thus far, DT has been more widely applied in engineering, making it highly relevant when contrasted with STEM-based learning approaches.

The application of STEM integrated with the DT thinking method, commonly referred to as STEM-DT, is a novel concept that enhances the quality of learning implementation. The DT approach can overcome infrastructure limitations and socio-economic gaps, creating a learning environment that improves students' experience and understanding through projects [24]. As a result, DT is a worthy focus that should be considered, implemented, and regulated adequately in Indonesia's education system to advance human resources [13].

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The discussion of DT has gained popularity and is recommended for continued application in education, particularly in Indonesia [3].

Evaluating the preparedness for implementing learning with the STEM-DT approach is essential due to the high potential of both models to encourage the acquisition of 21st-century skills. Assessing the effects resulting from the application of STEM-DT is necessary to determine the risks and to conduct an initial evaluation of the preparedness of both teachers and prospective teachers. Applying STEM-DT to early learners has demonstrated a favourable impact in enhancing the development of ideas, defining problems, designing, testing, collaborating, and communicating based on their level of thinking [15]. Although the usage of learning concepts with the STEM-DT approach in higher education is still limited, the results are comparable. DT is effective when applied to interdisciplinary learning, like STEM.

The promotion of practical activities and hands-on applications fosters interdisciplinary collaboration, nurtures creativity, and enhances student focus, as indicated by [41] findings. To implement STEM-DT, structured efforts are necessary to encourage and invite teachers so that they consciously desire to adopt this learning model. Establishing the readiness and understanding of STEM-DT is a crucial milestone that must be achieved. However, no instrument is currently available that can simultaneously assess STEM and DT skills. According to the available data, research conducted thus far has primarily focused on STEM aspects [14], [45], while DT has been the sole focus of other studies [7], [40]. Previous research has concentrated on developing STEM and DT instruments separately, but to obtain more comprehensive results in a relatively shorter timeframe, specialized instruments that can assess both STEM and DT abilities simultaneously are required.

The development and validation of the STEM-DT instrument as a learning approach model is a multifaceted process that involves several critical stages, include supporting theoretical determinations, expert review of assessments, and conducting confirmatory factor analysis (CFA) of the developed instrument. STEM-DT integration represents an innovative and contemporary pedagogical approach aimed at enhancing the quality of education. This study is focused on developing and validating a STEM-DT-based learning readiness instrument. The significance of the research instrument lies in its potential to bridge the theoretical gap in determining STEM-DT learning readiness, facilitating its integration into the curriculum.

1.1. Literature Review

This research focuses on the development of the STEM-DT instrument and its validation results. STEM and DT are two frameworks that have a significant impact on modern learning practices. STEM and DT are two frameworks that significantly impact modern learning practices. STEM emphasizes mastering technical skills and critical thinking, while DT provides an empathy-based approach to fostering innovation and problem-solving. Both are supported by robust theoretical frameworks that underpin their implementation and evaluation in educational contexts. Therefore, the following are explained the STEM in teaching and learning, the concept of DT, and the theoretical frameworks *of STEM-DT*.

1.1.1. STEM in Teaching and Learning

The STEM educational approaches have gained considerable popularity recently, leading educators to incorporate them into their classroom instruction. Many studies have demonstrated and validated the positive influence of integrating STEM into the curriculum on cognitive and non-cognitive development [1] and enhancing motivation and creative thinking [19], [22]. The general readiness of Indonesian schools, classrooms, teachers, and students to implement STEM is quite high on average. The development of STEM with modules illustrates this readiness [34]. Implementing STEM education is ongoing, as educators recognize its potential to promote student development. Integrating multiple disciplines in STEM learning allows students to solve problems more effectively than traditional methods, which rely solely on knowledge. Therefore, teachers must rethink the learning process and consider its practical application to achieve learning objectives [12], [23]. The ongoing implementation of STEM in classrooms requires reflection as part of the evaluation process. Improvement and development of STEM through lesson plans [10], [33], teaching modules [35], evaluation instruments, and integration into the curriculum are ongoing efforts [41].

1.1.2. Design Thinking (DT) Concept

Design Thinking (DT) is a cognitive model that facilitates problem-solving in learners. It has gained widespread acceptance in engineering and technology fields [5]. Its systematic and detailed thinking structure characterizes DT as an exploration process to produce and create products that are increasingly being adopted [25]. Studies on the implementation of DT in fields such as mathematics, science, engineering, and even social sciences [32] have shown that it offers numerous potential benefits and advantages for students [4], [30], [39].

In education and learning, the concept of DT is relatively new, and it requires time and effort to comprehend it fully. According to [30], understanding and implementing DT in the classroom can be challenging, especially for teachers who want to incorporate this thinking into their teaching. However, applying DT in learning can potentially train and equip students to think critically and solve problems independently [39]. Additionally, DT can improve interdisciplinary communication within organizations or groups by facilitating better collaboration [9]. Overall, using DT in education can foster creativity and independence in students and enhance collaboration and group communication.

1.1.3. Theoretical Framework of STEM-DT

The implementation of STEM-DT represents a novel educational approach that warrants consideration for integration in the classroom, particularly for those who have previously attempted to incorporate STEM into their learning experiences. This is because, as research by [34] suggests, students who are accustomed to STEM-based learning have the potential to enhance their academic proficiency, as well as their behaviour, communication skills, attitudes, and work readiness. Furthermore, the effective application of STEM can significantly improve these areas.

2. Methodology

The research methodology section outlines the study design, participant selection, instruments used, data collection process, and the procedures for data analysis. This section is divided into three subsections, which are elaborated as follows. The conceptual framework was developed based on validation result.

2.1. Study Design, Participants, and Sampling

The present study employs a cross-sectional descriptive research design to identify research problems at a specific time and evaluate respondents' phenomena, subjects, and attitudes [16], [28]. The study comprised 603 participants randomly selected from 1450 prospective teachers enrolled in a teacher professional program (Table 1).

Table 1. Respondent condition

Gender	**Age Group**			**Total**	
	Youth (0-25)	**Adult (26-49)**	**Senior (>50)**		
Male	144	80	63	1	144
Female	459	346	111	2	459
Total	603	426	174	3	603

2.2. Instrument and Data Collection

The STEM-DT questionnaire, which was employed as the research instrument, comprised of 43 questions that were designed based on the stages of STEM and DT and were derived from the supporting literature. Expert validation was conducted through Focus Group Discussions, which involved researchers with expertise in STEM education and lecturers who had taught DT courses within the past two years. The focus group discussion (FGD) results confirmed the validity of the indicators compiled in the questionnaire, as indicated in Table 2.

The STEM-DT questionnaire was created and disseminated through Google Forms to online respondents. The duration for completing the questionnaire was set at two months, with only one chance to do so. Initially, the questionnaire focused on the respondents' familiarity and participation in STEM and DT and their application of these methodologies in their classrooms.

Table 2. Exploration of STEM-DT components

STEM-DT Components	**Number**
Empathize and Ask (EA)	1-6
Define and Imagine (DI)	7-11
Ideate and Plan (IP)	12-22
Prototype and Create (PC)	23-33
Test and Improve (TI)	34-43

2.3. Data Analysis Procedure

The internal validity of the STEM-DT tool was examined through factor analysis. First, an Exploratory Factor Analysis (EFA) was carried out [42], followed by a Confirmatory Factor Analysis (CFA) [38]. The EFA determined the number of factors formed from 43 statement items in the STEM-DT questionnaire. To ensure appropriate data and adequate sample size, the Kaiser-Meyer-Olkin (KMO) test was conducted, resulting in a KMO value > 0.5 [11]. Additionally, Bartlett's Test of Sphericity (BTS) was used to determine whether there was a correlation between variables in the factor, with a BTS value <0.01 indicating a correlation between variables in the factor [26]. The external validity test of the STEM-DT instrument was conducted to assess its consistency when implemented in a broader context. This test evaluated the instrument's ability to analyze demographic factors influencing STEM-DT abilities. The demographic variables measured in this test were age and gender. To ensure the accuracy of the results, additional tests were conducted, including a multicollinearity test, a linearity test, and multiple regression analysis.

3. Results

The results of this study are presented in six sections, covering the development of the STEM-DT instrument, its implementation to assess STEM and DT skills, and an analysis of these skills before and after the application of STEM and DT in teaching and learning. The discussion started with the development of the STEM-DT instrument, then treatment was carried out on students to find out the implementation of DT stems in class and then asked for students' responses to the implementation of STEM-DT. Additionally, the effect of understanding STEM and DT on STEM-DT abilities is examined, followed by an external validity test of the instrument to evaluate its robustness and applicability.

3.1. STEM-DT Instrument Development

The initial analysis using KMO and BTS yielded promising results. The KMO value was 0.98 > 0.5, indicating that the sample size was sufficient for factor analysis. The BTS value was also < 0.01, providing additional confirmation that the assumptions for factor analysis had been met (Table 3).

This indicates that the analysis can proceed without any further concerns regarding the number of samples. Factor analysis was conducted using the parallel method [8] and standard eigenvalues > 1 [43]. The rotation method utilized varimax [29] and maximum likelihood estimation was performed with a minimum loading factor of 0.4.

Table 3. KMO and BTS analysis result

Kaiser-Meyer-Olkin	Bartlett's Test of Sphericity		
Overall MSA	X^2	df	p
0.980	15691.508	903.000	<.001

The results indicate the formation of three factors (Table 4), which are labelled according to their distinguishing characteristics. Factor 1 is identified as the identification and development of STEM-DT learning (IDL), Factor 2 represents innovation and collaboration in STEM-DT learning (ICL), and Factor 3 is designated as implementation and evaluation in STEM-DT learning (IEL).

Table 4. Factor fit model characteristics and indicators

Construct	Initial Eigen values	% of var.	Average interitem correlation	Alpha Cronbach	N	RMSEA	TLI	CFI
Identification and Development of STEM-DT Learning (IDL)	1.16	9.30	0.43	0.70	3	0.039	0.945	0.952
Innovation and Collaboration in STEM-DT Learning (ICL)	1.63	11.20	0.34	0.72	5			
Implementation and evaluation in STEM-DT learning (IEL)	19.97	28.70	0.50	0.97	34			

The characteristics of the factors formed are depicted in Table 4. The first factor, IDL, has an initial eigenvalue of 1.16, accounting for 9.30% of the total variance. The average correlation between items in this factor is 0.43, signifying a moderate relationship between them. The reliability of this factor is demonstrated by Cronbach's Alpha of 0.70, which is deemed acceptable. The second factor, ICL, has an initial eigenvalue of 1.63, accounting for 11.20% of the total variance. The average correlation between items in this factor is 0.34, indicating a weaker relationship than the first. However, this factor exhibits good reliability, as reflected by Cronbach's Alpha of 0.72.

The third factor, IEL, makes the largest contribution with an initial eigenvalue of 19.97, explaining 28.70% of the total variance. The relationship between the items in the IEL factor is robust, with an average correlation of 0.50.

Moreover, the factor's reliability is exceptionally high, as evidenced by its Cronbach's Alpha of 0.97. The IEL factor comprises 34 items demonstrating its content's depth and breadth.

The model fit results for all factors were excellent, as indicated by the RMSEA of 0.039, TLI of 0.945, and CFI of 0.952. These indicators suggest that the STEM-DT model is a very good fit.

However, one factor was removed due to its failure to meet the minimum factor loading requirement of 0.4, resulting in 42 items being distributed across the three factors formed.

The relationship between the factors' items is quite strong, as evidenced by an average correlation of 0.50.

The internal consistency of the IEL factor is also very high, with a Cronbach's Alpha of 0.97.

This factor contains 34 items that illustrate the depth and breadth of the content in the IEL factor.

The model fit results for all factors were excellent, with an RMSEA of 0.039, TLI of 0.945, and CFI of 0.952.

These values indicate that the STEM-DT model is an excellent fit. However, one factor was eliminated due to its failure to meet the minimum factor loading requirement of 0.4, resulting in only 42 out of the total 43 statement items distributed across the three formed factors.

Table 5. Goodness of fit index confirmatory factor analysis

Index	Value	Cut off value	Source	Criteria
X^2/df	2.270	<3.00	[21]	Good
Root mean square error of approximation	0.046	≤0.06	[17]	Good
Goodness of fit index	0.977	≥0.90	[6]	Good
Comparative Fit Index	0.931	≥0.90	[21]	Good
Tucker-Lewis Index	0.927	≥0.90	[21]	Good

The results of the CFA reveal that the model exhibits a satisfactory fit, as demonstrated by several Goodness of Fit indices (Table 5). The Chi-square/degree of freedom (X2/df) value of 2.270 is below the recommended limit of <3.00, there by indicating a good fit [21]. The RMSEA value of 0.046, which is lower than ≤0.06, also signifies low approximation error and excellent model fit [17].

The GFI of 0.977, higher than ≥0.90, suggests that a substantial proportion of the variance in the covariance matrix can be attributed to the model [6].

Furthermore, the CFI of 0.931 and TLI of 0.927, both exceeding ≥0.90, indicate that the model has a good fit and is not overfitting [17]. Consequently, all calculated GFI indices indicate that the tested CFA model is acceptable and consistent. The number of factors formed and the factor loadings of each factor after CFA are illustrated in Figure 1.

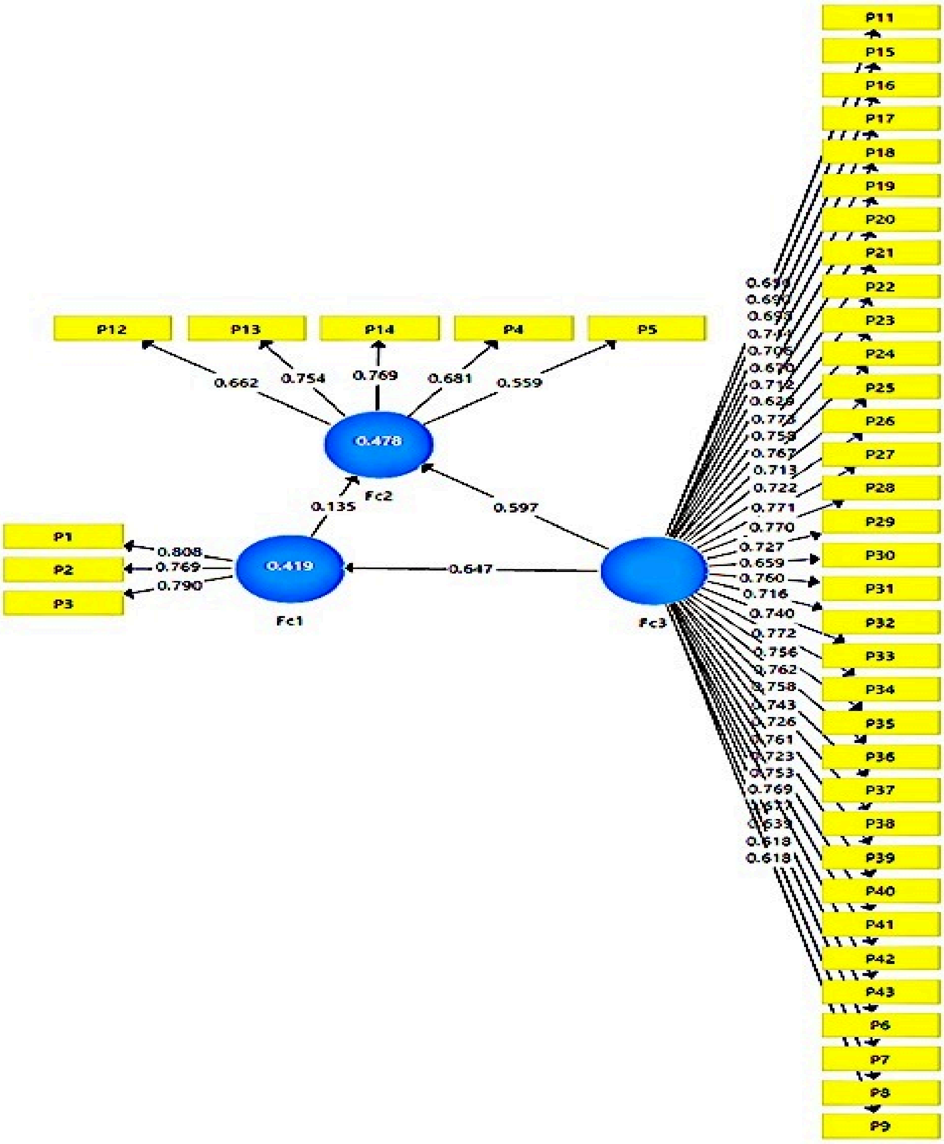

Figure 1. Factors and factor loadings formed after CFA

3.2. Implementation of Instruments to Reveal STEM and DT Skills

Measuring and evaluating the developed instrument's consistency necessitates respondents' participation. This process was conducted on a sample of 603 teachers and prospective teachers with prior STEM-DT learning experience. The STEM-DT skills were assessed using a questionnaire designed before and after integrating STEM and DT into the learning process. The implementation outcomes on each of the three factors are as follows.

3.3. STEM-DT Skills Before and After STEM Implementation in Learning

Additionally, the IEL factor shows less variation. The findings from the pre-and post-implementation analysis of STEM-DT ability in learning activities show significant differences in the two factors, IDL and IEL ($p<0.05$).

In contrast, the ICL factor exhibits no significant changes ($p>0.05$). The box plot visualization further supports these results, demonstrating clear distinctions in the mean scores for IDL and IEL between the pre-treatment (IS 1) and post-treatment (IS 2) stages.

3.4. STEM-DT Skills Before After DT Implementation (IDT) in Teaching and Learning

The box plot analysis and statistical tests have revealed notable differences in STEM-DT proficiency based on DT Implementation (IDT). As depicted in Figure 3, the distribution of values varies significantly between Before DT implementation (IDT 1) and After DT implementation (IDT 2) for the three factors. The t-test results indicate that these differences are statistically significant, as all factors measured exhibit p-values <0.05. These findings suggest that IDT significantly impacts the ability to identify and develop learning needs, promote innovation and collaboration in learning, and implement and evaluate learning in an integrated manner.

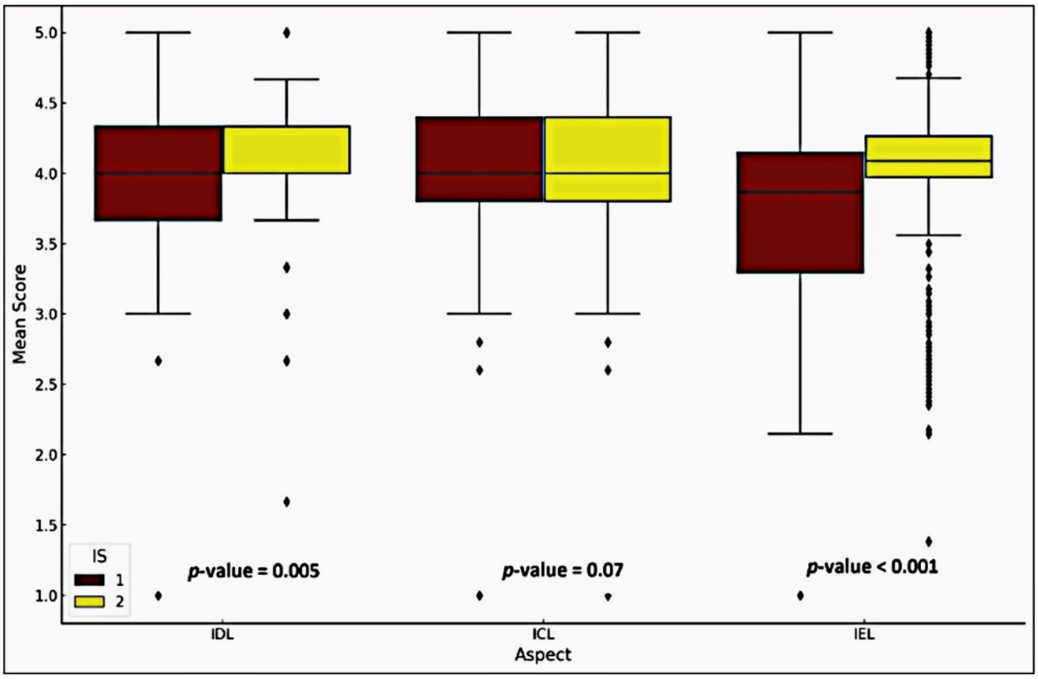

Figure 2. The capabilities of STEM-DT are related to three factors before and after the implementation of STEM in learning (IS 1 and IS 2, respectively)

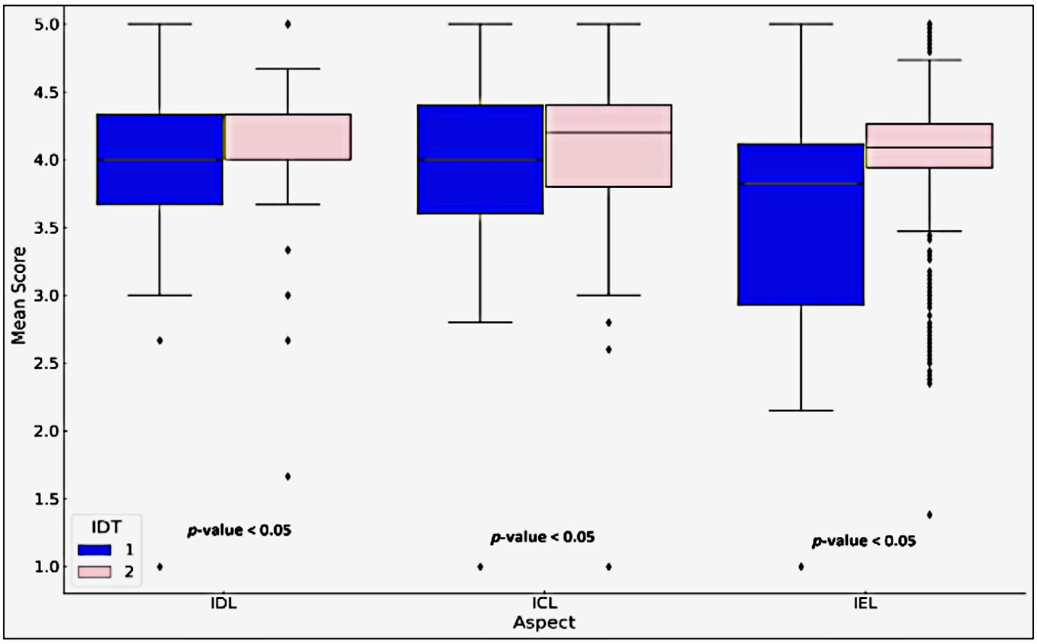

Figure 3. The STEM-DT capabilities were assessed based on three factors: before (IDT 1) and after (IDT 2), the implementation of DT in learning

3.5. Effect of STEM and DT Understanding on STEM-DT Ability

The outcomes of the examination of STEM-DT proficiencies before and after integrating STEM and DT in education demonstrated that STEM-DT skills following implementation surpassed those before implementation (Figure 2 and Figure 3).

This outcome is attributed to respondents' initial comprehension, especially regarding STEM and DT. To validate this hypothesis, a regression statistical analysis was performed to uncover the influence of initial understanding on STEM knowledge (PS) and DT knowledge (PDT). The condensed results of the multiple regression analysis are presented in Table 6.

Table 6. Results of the multiple regression analysis on the influence of PS and PDT

Factors	R-squared	Adj. R-squared	PS Coefficient	PS p-value	PDT Coefficient	PDT p-value
IDL	0.035	0.032	0.333	0.001	0.340	0.004
ICL	0.016	0.013	0.296	0.006	0.141	0.256
IEL	0.029	0.026	0.352	0.000	0.173	0.083

The regression analysis in Table 6 reveals that PS and PDT play crucial roles in various aspects of learning. Concerning IDL, PS and PDT exhibit a substantial positive correlation, with coefficients of 0.333 (p = 0.001) and 0.340 (p = 0.004), respectively. This suggests that higher levels of knowledge in STEM and DT are associated with improved identification and development of learning needs. This model accounts for 3.5% of the variance in IDL scores. For ICL, PS has a significant impact on ICL scores (coefficient = 0.296, p = 0.006), while PDT demonstrates no significant effect. This suggests that higher PS levels are associated with higher ICL and account for 1.6% of the variance in ICL scores. Regarding the IEL factor, PS shows a significant positive relationship with a coefficient score of 0.352, p < 0.001, while PDT exhibits a near-significant effect with a coefficient of 0.173, p = 0.083). This indicates that PS significantly contributes to IEL, while PDT has a smaller yet important influence. The model also accounts for 2.9% of the variance in IEL scores.

3.6. External Validity Test of Instrument

Having completed the internal validity assessment (EFA and CFA) and instrument consistency evaluation, the next and final step in instrument development is the external validity test. The purpose of conducting a multicollinearity test is to examine the relationship between independent variables, while the linearity test is designed to assess the connection between dependent and independent variables. The outcomes of these tests are presented in Table 7 and Table 8.

Table 7. Multiple regression linearity test

		Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)	598.946	5	119.789	1.281	.270
	Linearity	.000	1	.000	.000	1.000
	Deviation from Linearity	598.946	4	149.737	1.601	.172
Within Groups		55832.833	597	93.522		
Total		56431.779	602			

Table 8. Multiple regression multicollinearity test

		Unstandardized Coefficients		Standardized Coefficients	Collinearity Statistics	
Model		B	Std. Error	Beta	Tolerance	VIF
1	(Constant)	19.022	1.373			
	Age	.982	.539	.066	.964	1.037
	Gender	-7.691	.586	-.475	.964	1.037

Table 7 presents a linearity Sig value of 1.00 (p>0.05), suggesting a relationship between the dependent and independent variables. This finding is supported by the multicollinearity test (Table 8), which reveals that the tolerance value is close to 1, and the VIF value is within the range of 1. These results indicate that there is no relationship between the independent variables tested. A multiple regression analysis was performed following these assumption tests, with the results in Table 9.

Table 9. The outcomes of the multiple regression analysis involve demographic factors such as age and gender

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R	R square
Model	B	Std. Error	Beta				
1 (Constant)	56.944	2.206		25.811	.000		
Age	1.773	.865	.076	2.049	.041	.445[a]	.198
Gender	11.450	.941	.453	12.166	.000		

a. Dependent Variable: Stem_DT

Table 9 showcases the relationship analysis between the independent variables, (gender and age) and the dependent variable (STEM-DT). This regression model has a constant value of 56.944 and a t-value of 25.811, with a significance level of 0.000, which indicates a highly significant result. The regression coefficient of the age variable is 1.773, with a standard error of 0.865, a t-value of 2.049, and a significance level of 0.041, indicating that age has a significant effect on STEM-DT.

The regression coefficient of the gender variable is 11.450, with a standard error of 0.941, a t-value of 12.166, and a significance level of 0.000, suggesting that gender also has a very significant influence on STEM-DT. The R-value of 0.445 signifies that this model exhibits a moderate strength of relationship between the independent and dependent variables. Additionally, the R square value of 0.198 implies that approximately 19.8% of the variability in STEM-DT can be explained by the gender and age variables. These findings are further substantiated through the post hoc test detailed in Table 10.

Table 10. The Post hoc test results of gender and age variables

Metode dan Variabel		N	Subset for alpha = 0.05	
			1	2
Duncan[a,,b]	Gender			
	Males	144	70.97	
	Females	459		82.05
Duncan[a,,b]	Age Group			
	Adults (26-50 years)	174	79.16	
	Young (0-25 years)	426	79.47	
	Senior (>50 years)	3		82.38

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 5.905

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 10 illustrates the disparity in STEM-DT proficiency based on gender and age. The data reveal that males possess an average STEM-DT proficiency score of 70.97, whereas females exhibit a higher average score of 82.05. Concerning the age variable, the mature age group (26-50 years old) achieves an average score of 79.16 in STEM-DT proficiency, while the younger age group (0-25 years old) attains an average score of 79.47. The senior age group (>51 years) demonstrates the highest mean score of 82.38. Although there are variations in the mean STEM-DT proficiency scores across different age groups, the differences were not found to be significant compared to the gender variable. This result suggests that gender has a more pronounced impact on STEM-DT proficiency than age.

4. Discussion

This research aims to develop and validate a questionnaire to assess the knowledge and perceptions of educators and prospective educators towards the STEM-DT teaching approach.

The creation of STEM-DT involves combining various components that ultimately resulted in five definitions: 1) Emphasizing and Asking (EA), 2) Defining and Imagining (DI), 3) Ideating and Planning (IP), 4) Prototyping and Creating (PC), and 5) Testing and Improving (TI).

The compatibility of the STEM-DT components with the factor analysis results is presented in Table 11 below.

Table 11. Conformity of STEM DT components with analyzed factors

STEM-DT Components	Factor Identification
Empathize and ask (EA)	IDL
Define and Imagine (DI)	IDL
Ideate and Plan (IP)	ICL
Prototype and Create (PC)	IEL
Test and Improve (TI)	IEL

After being validated by 603 teachers and prospective teachers, three factors emerged that were aligned with the STEM-DT components, resulting in three factors: 1) Identification and Development of STEM-DT Learning (IDL), 2) Innovation and Collaboration in STEM-DT Learning (ICL), and 3) Implementation and Evaluation of STEM-DT Learning (IEL).

Empathy is defined as a person's ability to understand and appreciate the feelings of others by placing themselves in the other person's situation [18]. This ability is important in establishing effective communication, which facilitates the communication process in a learning community. This process helps to generate and communicate ideas, which are crucial components of STEM-DT as shown by [36]. The idea generation and planning process is linked to factor 2 (ICL) in this study. Multidisciplinary integration in STEM learning requires a strong foundation in innovation, essential for problem-solving. In this context, the role of DT is to foster innovation, creativity, and ideas, helping students to think more systematically and directionally [2].

Drawing from the findings of this study, it can be concluded that a total of 34 questionnaire items were gathered to assess the IEL factor. This implies that a comprehensive and integrated learning and evaluation process should be implemented to combine STEM-DT successfully. DT, which involves empathy and prototyping ideas, is essential to STEM [37]. Therefore, STEM-DT has the potential to equip learners with the necessary skills to tackle problems and develop solutions. Additionally, the results of this study indicate that women tend to exhibit a greater inclination towards STEM-DT than men [20]. This can be attributed to the strong influence of empathy, which is a predominant variable in implementing STEM-DT learning in the classroom.

5. Conclusion

The research findings indicate three main factors identified from EFA, which include 1) recognizing and nurturing learning needs, 2) promoting innovation and collaboration in learning, and 3) implementing and assessing integrated learning. The CFA results demonstrate that these factors meet the fit criteria, as evidenced by the RMSEA value of 0.046, CFI of 0.931, and TLI of 0.927. Moreover, the external validity test results show that the instrument can effectively measure STEM-DT skills across various demographic factors. The study found that women have higher STEM-DT skills than men, scoring 82.5.

Additionally, the results of the implementation revealed that the instrument could differentiate STEM-DT skills across different age groups, with the elderly (>50 years) having the highest mean ability compared to younger individuals (0-25 years) and adults (26-49 years), scoring 82.38.

While the instrument proved effective, its application was limited to general contexts, leaving its impact in specific disciplines unexplored. These results underscore the need for targeted interventions to enhance STEM-DT skills, particularly for underrepresented groups. Future research should focus on integrating STEM-DT frameworks into specific fields, exploring long-term skill development, and investigating contextual factors influencing demographic disparities. This would provide deeper insights into STEM-DT's potential to transform learning and innovation across educational and professional landscapes.

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