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Development and validation of an instrument to access elementary school preservice teachers' understanding towards STEM education

Galih Albarra Shidiq[1]*, Agung Purwa Widiyan[2], Saori Nishikawa[3], Lidwina Felisima Tae[4]

[1]Alma Ata University, Brawijaya street No.99, Jadan, Tamantirto, Kasihan, Bantul, Daerah Istimewa Yogyakarta 55184, Indonesia
[2]Khon Kaen University, 123 Moo 16 Mittraphap Rd., Nai-Muang, Muang District, Khon Kaen 40002, Thailand
[3]Kumamoto University, 40-1 Kurokami 2 Chome, Kumamoto 860-8555, Japan
[4]Universitas Timor, Sasi street No. KM 09, Kefamenanu, Timor Tengah Utara, Nusa Tenggara Timur 85613, Indonesia
**Correspondence: galihalbarra@almaata.ac.id*

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Abstract

The instrument could be an important tool to measure the current situation of preservice teachers' understanding of STEM education at the elementary school level. The study aimed to develop and validation of the scale of instrument test of elementary school preservice teachers' understanding of integrated STEM. The scale of the instrument was developed based on the items results of theoretical background review and the experts' suggestions with the total number of participants in this study is 124 Indonesian elementary school preservice teachers' understanding from the university at the central regions of Indonesia were voluntarily selected to fill out the test. The primary component analysis generated by the components and sub-components of each item could be measured by the Cronbach's alpha of .940 value and the finding indicated that the scale is valid and reliable to interpretation as a vehicle for evaluating the elementary school preservice teachers' understanding of STEM education. The implication of this study was about the possibility to implementation STEM into the classroom which is related to improve 21st century skills.

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Introduction

Since 2003, the Programme of International Student Assessment (PISA) has been continuously examined and reported to the majority of Indonesian students present low level categories of scientific literacy (OECD, 2017; Schleicher, 2018). The series of the international test also found that Indonesian students present the lack of interest to pursue STEM careers (Schleicher, 2018). This problem happens not only in Indonesia but also in other countries such as Malaysia, South Korea and the United States by which students do not think of STEM as part of the curriculum and their future careers (Shahali et al., 2016; Shin et al., 2018; Roberts et al., 2018). Other studies conducted with Indonesian students confirm that students present low interest and ability level in STEM (Suprapto, 2016; Blackley et al., 2018; Suwono et al., 2019). Unfortunately, the results are in opposite direction with the demand for human workforces in the 21st century in STEM capabilities (Trilling & Fadel, 2009; Schleicher, 2018).

Recent studies indicated that students' performances and understanding in science learning are closely related to the competencies of the new pedagogical teaching approach (Al Salami et al., 2017; Wang et al., 2011; Thibaut et al., 2018; Park et al., 2016; Stohlmann, 2019; Shidiq et al., 2022). For instance, a study by Al Salami et al. (2017) examined that teachers' competencies play critical position in the implementation of new pedagogical approaches to provide students' knowledge and skills achievements. Park et al. (2016) reported that teachers' understanding of a new pedagogical approach, namely STEAM education approach impacts the effectiveness of new approach in the real classrooms. Stohlmann (2019) found that teachers' understanding of new teaching implementation methods can help students to develop the learning conception. Shidiq et al. (2022) concluded that teachers' competencies related to the inquiry, innovation, reflection, mutual respect, personal connection, collaboration, and community to appropriate with the 21st-century professional criteria. Thus, to promote students' ability and interest in STEM fields, first of all, we should know what preservice teachers do understand about STEM education and what competencies of learning science at the school level. This information should be advanced for future teachers and curriculum developers who responsible for promoting STEM education.

Research on integrated STEM can inform preservice and in-service teachers, curriculum makers, and stakeholders to pinpoint the challenge of current teaching practice. As reported by Council (2014) STEM contains teaching in a cross-disciplinary approach by using the fourth disciplines of science, technology, engineering, and mathematics and building on students' content knowledge and understanding to developing across the four disciplines through recognizing the powerful linkage between STEM areas which fostering the design, creativity, and innovation of students. STEM teaching is an instructional approach that can promote students' active learning and understanding of the scientific conceptual and contextual in real problem situations (Stohlmann et al., 2012; Bybee, 2013; English, 2016). This research also important to facilitate students' learning by exploring their knowledge and developing 21st-century skills such as creativity, critical thinking, collaborative problem solving, and communication (Council, 2012; Council, 2014; Stehle & Peters-Burton, 2019). STEM is focusing on science and mathematics and the critical role of engineering and technology to prepare students faced in real-world situations (English, 2016). This view of STEM teaching is using on the large quartet of each discipline and the acronyms of STEM teaching could be many different insights on the acronyms of STEM integration by using on the large quartet of each discipline (Bybee, 2013). However, it is important to assess what preservice teachers think and defines of STEM education at the beginning rather than other teaching methods that they already know as they will become school teachers (Stinson et al., 2009). Thus, the development of STEM instruments can create a new challenge and opportunity for researchers since STEM education in every country, which is different characteristics.

Currently, the STEM instrument consists of domains of understanding to measure preservice teachers' views on integrated STEM education. Literature indicates that preservice teachers' competencies can respond to accomplishment the different idea of integrated STEM (Denessen et al., 2015; Al Salami et al., 2017; Thibaut et al., 2018; Aldahmash et al., 2019), the competencies could impact to preservice teachers beliefs of teaching and learning of integrated STEM implementation (Nathan & Koedinger, 2000; Wang et al., 2011; Park et al., 2016; Margot & Kettler, 2019), and their abilities may influence to the way of teaching integration and achievement of students' learning motivation (Wang et al., 2011; Stohlmann, 2019; Shin et al., 2018). However, the development of an instrument also plays important parts to access the limitation of STEM integration. Based on the literature review, there are some studies has developed the STEM instruments which focusing on STEM integration. For instance, Unfried et al. (2015) was developed STEM instrument to measure students' abilities and career interests of STEM integration. Benjamin et al. (2017) used to develop the instrument to access the dimensions of students' attitudes, knowledge, and skills of STEM literacy. In similar study, Arikan et al. (2020) developed the instrument to measure students' views of STEM competencies on scientific literacy. Appianing & Van Eck (2018) developed the instrument to examine the values and expectations of students' motivation in STEM integration and Zhuang et al. (2019) used to develop the instrument to measure STEM attributes on students' learning experiences. However, Wahono & Chang (2019) developed the instrument to survey teachers' skills of STEM. The limitation of these instruments is not enough to explore the condition of teachers' views on STEM integration and the suggestions from previous studies were to possibly construct the components of attributes related to teachers' competencies, perspectives, and characteristics of integrated STEM education. Therefore, to address the limitation of research and discussion on the elementary school preservice teachers' views of STEM integration, this study presents the development and validation of an instrument to access the elementary school preservice teachers' competencies of integrated STEM. It could be examined how does the development and validation of the instrument process. To do this, we hope that the results of this study will gain the possibility of current instruments used to measure the differences between preservice teachers' thinking and understanding of integrated STEM.

Method

Research Design and Collection

This study carried out to develop an instrument which used to measure the current competencies of elementary school preservice teachers' views on STEM integration through providing information about what they think based on the experiences. We developed the instruments by using Research and Development (RnD) which consists of the four steps of the design of validation such as create a plan, construction, evaluation, and validation for purposing to collect the data from the sample of the target group population and evaluate of various variables (Creswell, 2012). Furthermore, the instrument presents to explore understanding in-depth on current situations and aims to examine the logical thinking of respondents (Merriam & Tisdell, 2015). However, the instruments' quality was established by authors based on the validity and reliability. Therefore, the instrument consists of the items to explore the general information and a core content related to competencies (concept learning, problem-solving, differential focus, propositional understanding, case understanding, strategic understanding).

Research Participants

The instrument was distributed to 124 elementary school preservice teachers from the central regions of the university in Indonesia which consist of the elementary school levels were asked to fill out the questionnaire as a volunteer. The demographic data information comprised of the gender, age, and teaching experience. The purpose of this research was to obtain the understanding of a wide range of participants which addressing what happens in the current situations (Gordon & McNew, 2008; Merriam & Tisdell, 2015).

Procedure

To address the limitations and recommendations of existing instrument developed by several researchers that focusing on STEM integration (Unfried et al., 2015; Benjamin et al., 2017; Appianing & Van Eck, 2018; Zhuang et al., 2019; Wahono & Chang, 2019; Arikan et al., 2020). This instrument was developed by following the steps in developing an instrument suggested by Creswell (2012) which contains step (1) planning divided by the statement of the test purpose and target groups as the main focus of our research, literature review construction, identify and define of the test domain to provide the general tool of understanding preservice teachers' competencies of integrated STEM, step (2) construction consists of creating the items pool and developing the new items by adopted by Riggs (1988) Likert-scale rating to begin the point range which consist of strongly agree, agree, uncertain, disagree, and strongly disagree. Then, specified score from 5 for strongly agree, 4 for agree, etc. Also, this instrument was constructed by the theoretical background of the cognitive, affective, concern, interest, content, and pedagogy of integrated STEM through the sample test components of implementation of STEM toward science and math teaching (S-Cg), teaching with problem-solving (S-Af), teaching STEM disciplines (S-Cn), teaching STEM approaches (S-It), STEM competencies (S-Ct), STEM teaching and learning (S-Pd), step (3) quantitative evaluation comprises of distributing the pilot test items and analyzing the reliability test. On the first of section, we distributed the instrument to 35 participants as a pilot testing items and receiving the validator/ experts' feedback and we distributed to the population of preservice teachers following the recommendation from Cochran (1977) who mentioned about the sample size of the study could be more than 100 participants which indicated to consideration of instrument can be used and the small sample size is limited of the parameter numbers for the researcher who cannot explore the development scale to determine a total population as the sample size, and the step (4) validation separated by the face validity and pilot testing. The four steps of developing the instrument can be seen in figure 1.

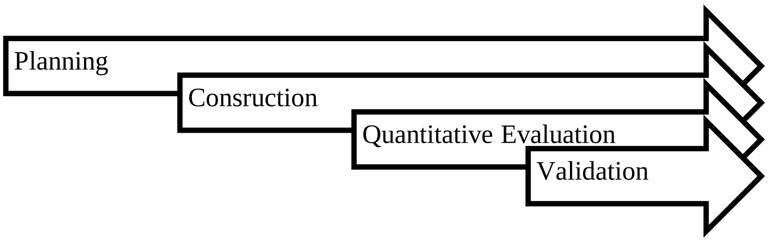

Figure 1. Research Steps of Developing Instrument of This Study

Statistical Analysis

The domains of the competencies towards integrated STEM was created on the basis of Likert-scale rating (Riggs, 1988) which consist of the level starting from the strongly agree, agree, uncertain, disagree, and strongly disagree. Then, we constructed the instrument domains into the sub-domain of cognitive, affective, concern, interest, content, and pedagogy of integrated STEM and creating the code of test components such as implementation of STEM toward science and math teaching (S-Cg), teaching with problem-solving (S-Af), teaching STEM disciplines (S-Cn), teaching STEM approaches (S-It), STEM competencies (S-Ct), STEM teaching and learning (S-Pd). However, to access the interval consistency of each domain, we used the reliability of instrument by analyzing the Cronbachs' alpha values. Thus, the Reliability of statistics was presented by Cronbach's Alpha = .940 from 28 test items which determining tools can be trusted. This research was conducted by the several steps to analyze and interpret the data from means values and standard deviations and using the Kolmogorov Smirnov test to examine the compliance of the variables a normal distribution as a significant relationship between the variables tested (Hinkle et al., 2003). Therefore, the data performed as follows of the descriptive statistics was to describe the demographic data information of the participants and the principal components analysis of items test as identify the components of items by examining the correlations and variances (Lever et al., 2017). Then, the relationship of the competencies of integrated STEM education was calculated by using the descriptive statistics (utilizing Microsoft Excel and SPSS). The Spearman's correlations test as the non-parametric test was used to determine the normal distribution to know whether the correlation of the strength and the weakness of the correlation that Evans & Durant (1995) suggested to the absolute value r =.00 - .19 which refers to relationship it is "very weak", .20 - .39 "weak", .40 - .59 "moderate", .60 - .79 "strong", .80 - 1.0 "very strong. However, in the statistical test, this was used to decide the level of $p<0.05$ that has been accepted as the indicator of difference and the factor loading was used to categorize based on the scale of greater than > .30 (consideration the level minimum), >.40 (more significant), and >.50 (nearly significant) (Black & Babin, 2019).

Results and Discussion

Participants Characteristics

Many participants in this study came from female with 80 respondents took part on this research. However, the participants from male was lower than female with 44 respondents. This result was surprising and indicating the female was the highest interested to learn STEM education which removing the barriers of research by Chavatzia (2017) that suggested the number of female interests in a STEM field is lowest around 35% usually. In another hand, the female had the gap in learning science which indicated a female was less than male and female was less involved in the learning experience and low inability which impacted to report of gender differences in particularly curriculum and pedagogical characteristics (Witherspoon et al., 2016). Therefore, Dyehouse et al. (2017) argued the gender can take part on male than female measuring by the cognitive rigidity of their mindset while female preservice teachers can find the idea to grab the pressure in response to emotional reaction.

Development of STEM Instrument

Prior to analyse the instrument, we conducted the assumption of testing for the descriptive statistics which comprises of mean scores and standard deviations of the components and sub-components of each item towards integrated STEM education by using Likert-scale point applied to starting from the minimum value (1) to the maximum (5) for every question item (see Table 1). However, the Kolmogorov Smirnov test results presented that K-S test = 0.2 indicates the variables in the normal distribution which identify the significant relationship among the variables tested (Hinkle et al., 2003). Also, we constructed the instrument STEM item from the domain of understanding into the sub-domain of cognitive, affective, concern, interest, content, and pedagogy of integrated STEM and generate the code of each components, namely implementation of STEM toward science and math teaching, teaching with problem-solving, experience in science, teaching STEM disciplines, teaching STEM approaches, STEM competencies, STEM teaching and learning

Table 1. Components and Sub Components of STEM Understanding

Components	Sub Components	Mean	SD
STEM Understanding	Cognitive	3.82	0.86
	Affective	3.72	0.79
	Concern	3.49	0.71
	Interest	3.72	0.78
	Content	3.75	0.93
	Pedagogy	3.53	0.79

Thus, to examine the relationship of each variable in this study, we used the testing of Spearman's correlations coefficient test in order to find out the significant relationship of each competencies (see Table 2). We tested the Spearman's correlations value among three components and seven sub-components and found the significant relationship of each variable ($p < .05$). The explanation of correlation coefficients had presented the significant relationship (r) among variables with the strength or weakness relationship between positive and negative connection (Evans & Durant, 1995). Therefore, we found that R and R Square of each variable could inform the simultaneous contribution to the factor predictors regarding to the components, data analysis showed the regression analysis obtained results. It was measured to be a predictor variable whereas attitudes, perceptions, and knowledge were familiar to dependent variable and the intention of examining this effect equation was to identify the component has the most influences to the predictor components, namely gender and teaching experience. We found that the competencies of preservice teachers has positive relationship to gender and teaching experience closely related to their understanding of teaching STEM.

The transformations of preservice teachers' attributes if comparing to the demographic data such as gender and teaching experience of preservice teachers could be considered to the aspects of their attributes that affect to STEM teaching in the classroom. Thus, Al Salami et al. (2017) described that gender, school, education level, and discipline experiences may influence preservice teachers' attributes in which creating their competencies to have a positive action, preparedness to work in teamwork, and indicated the positive response activities. Likewise, Thibaut et al. (2018) explained that teachers who found the great personal background characteristics could be provided to the positive correlation with their attributes such as a good attitude may influence to a high professional development of STEM teaching and impacted to the emphasis of facilitating in the school context connected to resource and time allocate in teaching and learning.

Table 2. The differences between preservice teachers' understanding to demographic data

Components	Namely	Beta	p<0.01	R	R Square
STEM Understanding	1 (Constant)			.090	.008
	Gender	.005	.943		
	Experience	.050	.512		

Reliability of Instrument

Analyze the level of instrument reliability was done after finding the data on the result of the respondents' tests results by using Cronbach's Alpha method which showing the value of internal consistency of domain items of all STEM components and sub-components was greater more than .6. As we found that the highest value of preservice teachers' understanding found at the domain of S-Ct (.825) and the lowest value is in the domain of S-Cn (.667). all of these values were considered to acceptable of internal consistency of the reliability of Cronbachs' alpha between STEM components. Therefore, the Cronbachs' alpha values showed .940 of all items which indicated as a reliable and the interval consistency of each item domain found that instrument can be interpreted. We analyzed the instrument by calculating the mean values and standard deviations and Kolmogorov Smirnov test was used to verify the relationship of each variable (Hinkle et al., 2003).

Table 3. Reliability of STEM Instrument

Components	Sub Components	Cronbach' Alpha
STEM Understanding	Cognitive (S-Cg)	.714
	Affective (S-Af)	.763
	Concern (S-Cn)	.667
	Interest (S-It)	.695
	Content (S-Ct)	.825
	Pedagogy (S-Pd)	.807

Validity of Instrument

In order to analyze the validity of instrument, we conducted the content and construct validity. The content validity was examined to analyze the sustainability between items and characteristics of the elementary school preservice teachers' attributes that wanted to be measured. In this study, content validity was evaluated by the experts and we used the method of content validity analyze by applying CVR which suggested by Wilson et al (2012). Thus, the instrument consists of 10 items which purposing to explore the demographic data information of the participants such as gender, age, and teaching experience, and 28 items were constructed to measure cognitive, affective, concern, interest, content, and pedagogy. Then, we asked to the experts to give the score in the range of 0 until 1 in each item. According to Wilson et al. (2012) argued that score 1 means if our item is significance to the standard and 0 means for the item is not significance to the standard of item. The results of the content validity can be seen in Table 5. The critical value of CVR could be accepted if the value for CVR is .78 with the significance level alpha (0.05). From the total items that we found, there are some instrument could be revised and changed which suggested by the experts and can be used after several revision. The content validity index (CVI) showed a value of 0.8. From 28 items has analyzed by authors and we found that three items with the item number 15, 22, and 28 should be revised (CVR = .6) and 1 item should be changed in advance by consulting with the experts in order to gain the revision on these items. For example, the experts suggested these items are related to the competencies and another item should be changed to should be changed the sentence such as “I don't quite sure that they will have the same reason with you”. However, other items are appropriate and could be accepted to be interpreted.

Table 4. Analysis of Content Validity

Item	Relevant	Not Relevant	CVR	Interpretation	Item	Relevant	Not Relevant	CVR	Interpretation
1	5	0	1.0	Appropriate	15	4	0	1.0	Appropriate
2	5	0	1.0	Appropriate	16	5	0	1.0	Appropriate
3	5	0	1.0	Appropriate	17	5	0	1.0	Appropriate
4	5	0	1.0	Appropriate	18	5	0	1.0	Appropriate
5	5	0	1.0	Appropriate	19	5	0	1.0	Appropriate
6	5	0	1.0	Appropriate	20	5	0	1.0	Appropriate
7	5	0	1.0	Appropriate	21	5	0	1.0	Appropriate
8	5	0	1.0	Appropriate	22	4	0	1.0	Appropriate
9	5	0	1.0	Appropriate	23	5	0	1.0	Appropriate
10	5	0	1.0	Appropriate	24	5	0	1.0	Appropriate
11	5	0	1.0	Appropriate	25	5	0	1.0	Appropriate
12	5	0	1.0	Appropriate	26	5	0	1.0	Appropriate
13	5	0	1.0	Appropriate	27	5	0	1.0	Appropriate
14	5	0	1.0	Appropriate	28	4	0	1.0	Appropriate

The experts' suggestions helped the authors develop the instrument and became valuable advice to improve for us. To construct validity, we constructed the instrument by analyzing the exploratory factor analysis (EFA) which was performed by using SPSS for Windows program. As we analyzed by using Keiser-Meyer Olkin (KMO), the sample adequacy test showed .907 which indicated that the variables are factorable and correlated in the significance to Barlett’s Test of Sphericity ($p < .05$). The result indicated that variables were correlated and the Barlett test was a significant result. This finding is enough to continue into the factory analysis. The value of KMO was higher than the recommendation from Beavers et al. (2013) who described that the correlations of variables should be more than .709 which can be provided enough evidence to justify the factory analysis. The result of exploratory factor analysis of all items can be seen in Table 5.

Table 5. Analysis of Content Validity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.907
Bartlett's Test of Sphericity	Approx. Chi-Square	4532.613
	df	780
	Sig.	.001

Conclusion

This study developed a practical understanding of elementary school preservice teachers. The instruments used to explore the information of gender, age, and experience, and employed to evaluate teachers' competencies and divided into the cognitive, affective, concern, interest, content, and pedagogy towards STEM education at the basic level. The instrument was demonstrated the strong evidence of content and construct validity and the internal consistency reliability. The participants took part in this study is 124 elementary school preservice teachers came from the central regions of Indonesia. However, the majority of participants came from the female with 80 participants compared to male was lower than female with only 44 respondents. Therefore, most of them had been working as teachers with teaching experience at least 6 months until 1 year in the public and private school of Indonesia. The scale of our development and validation of the instrument can be used as a vehicle for the feedback to improve elementary school preservice teachers' competence levels. Furthermore, this instrument is possible to use in exploring to the competencies especially on their understanding towards integration STEM education. However, there are some suggestions for the further study which is conducting this research, we hope that the next researchers, stakeholders, and curriculum makers could be constructed on the components or sub-components regarding to the current problems faced by teachers towards integrated STEM education.

Credit Authorship Contribution Statement

Galih Albarra Shidiq: Conceptualization, Methodology, Implementation, Software, Visualization, Data collection, Initial data analyzation, Writing–original draft, review & editing. **Agung Purwa Widiyan:** Conceptualization, Methodology, Implementation, Data collection, Initial data analyzation, Writing–review & editing. **Saori Nishikawa:** Conceptualization, Methodology, Research adviser, Supervision, Writing-review & Editing. **Lidwina Felisima Tae:** Conceptualization, Methodology, Review & editing, Visualization and Formal analysis.

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