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DEVELOPMENT AND VALIDATION OF A SURVEY INSTRUMENT (AKA) TOWARDS ATTITUDE, KNOWLEDGE AND APPLICATION OF STEM

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Abstract. *The development and deployment of STEM education in every continent and country are different. An instrument to access the current situation of the application, knowledge, as well as attitude towards STEM education, is necessary. This research aimed to design and develop a valid instrument that can be used to assure the quantitative degree of attitude, knowledge, and application of STEM (AKA) by science teachers. Research data were collected from 137 Indonesian secondary school science teachers. In order to determine the validity of the scale, reliability test, exploratory factor analysis (EFA), as well as the content and face validity from experts were used. Results showed that the designed and developed AKA instrument was adequate to reliabilities and validities as well as can be used to collect data. The development of AKA instrument enables users worldwide to obtain information about the development of STEM as well as the problems and challenges faced by science teachers in the field. Further work is also suggested.*

Keywords: *science teachers, STEM education, survey instrument.*

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Introduction

Innovation and development of education are needed to answer the demands of rapid changes in the progress of era and technology. STEM education was present to respond to these needs. STEM is a unique content area that acknowledges the interdependence of science, technology, engineering and mathematics (English, 2016). Recently, in the field of education research, STEM education has grown to be a trend. The first term of STEM that emerged in America more than a decade ago (Honey, Pearson, & Schweingruber, 2014), has now expanded throughout the Western as well as into Asia. During this time, efforts have been made by researchers and educational policymakers in each country to develop a reform and initiative to shape teaching and learning and try applying STEM on many educational units in their respective regions (Siew, Amir, & Chong, 2015; Wahono, Rosalina, Utomo, & Narulita, 2018). Moore et al. (2014) argued that the connections between the subjects and real-world problems are a connecting way to incorporate some or all of the four disciplines of science, technology, engineering, and mathematics (STEM) into unit or lesson or even into one class to promote school curriculum integrated STEM education. Honey et al. (2014) asserted that far from being a single, STEM education approach composes some level of connection that involves a space of many experiences. The experiences could take place in a broad range such as throughout a curriculum, entire school or a single course, in one or several class periods, or even be covered in any out of school teaching and learning activities. However, every single type of integrated STEM education encourages different things such as outcomes, resource needs, design approaches, and application challenges.

Therefore, teachers are a vital key as at the main guard of STEM implementation in most countries around the world (Aslam, Adefila, & Bagiya, 2018; Watermayer & Montgomery, 2018), especially teachers who teach science subjects. Researches of Ruiz et al. (2014) and Kola (2013) showed the importance of science teaching in education levels. They argued that the purpose is to prepare technologists and scientists needed for the development of innovation and research as a foundation for the economic welfare of an emerging economy as well as the development of many

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nations. However, the development and deployment of STEM Education in every continent and country are different. Some countries are already implementing it at an advanced level, while some countries are still in the introduction and trial stages (National Audit Office, 2010). Therefore, an instrument to evaluate the attitude, knowledge and even application (AKA) of STEM Education is necessary.

The current developed AKA instrument encompasses three domains at once that include STEM attitude, knowledge and application by the teacher. Based on review literature, some previous studies have also developed related instruments on STEM. Lam, Doverspike, Zhao, Zhe, and Menzemer (2008) developed an instrument to know the STEM career interest in middle school students. Meng, Idris, Eu, and Daud (2013) also developed a survey instrument to elicit perceptions of secondary school students on the STEM-related subjects in the school assessment practices. Ibrahim, Aulls, and Shore (2017) developed an instrument to survey the STEM for bachelor students' achievement values of inquiry engagement. Nevertheless, those kinds of STEM survey instrument have a function for eliciting information from students.

Other studies developed instruments that focused on the teachers. El-Deghaidy and Mansour (2015) have developed an instrument focused on science teachers' perceptions of STEM Education. Another research, Vennix, Brok, and Takonis (2016) have developed a survey questionnaire to assess the perceptions of STEM-based outreach learning activities both for the students and teachers in secondary education. However, this instrument has not been comprehensive enough for general use. The instrument has a specialty such as only to elicit data regarding teacher perception of STEM-based outreach learning activities. That instrument would be a problem to obtain the teachers' perception of STEM in general, without preceded by any STEM activities. For instance, an instrument used to get teachers' attitude, knowledge, and application simultaneously regarding STEM education as well as the problems and challenges faced by teachers on the particular area, country, or global. Moreover, there is limited research that develops survey instruments focusing specifically on science teachers. One solution is to re-evaluate, modify, combine, and reconstruct the instruments (Summers & Abd-El-Khalick, 2018) into a single instrument by convergence with an existing STEM education framework: a framework for K12 science education (NRC, 2012). However, these approaches cannot overcome the ingrained problems of existing instruments. The AKA instrument simply answers the needs of science teachers, as we have known the vital role of a science teacher (Kola, 2013; Ruiz et al., 2014) in quantitatively measuring the levels of attitude, knowledge, and application of STEM.

Teachers' Attitude, Knowledge and Application of STEM

Attitude, knowledge, and application (AKA) are the three main words that often appear in the assessment, especially in education. The definition also has a broad meaning. The first aspect introduced here is the attitude. Maio and Haddock (2014) argued that the term attitude can be defined in ample ways. Pryor, Pryor, and Kang (2016) defined attitude as negative, positive, or neutral feeling regarding some behavior or object. Then, in term of direction and strength, the attitude can vary such as a spectrum from extremely unfavorable to extremely favorable. Ajzen (2005) and Maio and Haddock (2014) explained that an overall assessment of an object in several conditions such as unpleasant or pleasant, and bad or good is a definition of the term attitude. Therefore, in this research "attitude" indicates whether the science teacher agrees or disagrees with the application of STEM, at the time of the students' classroom learning, and the students' sense of curiosity towards STEM, as well as what is the teacher thinking and feeling about STEM. Al-Salami, Makela, and de-Miranda (2017) proved that primary teachers need to develop both skills and attitudes toward interdisciplinary teaching. To determine secondary teachers' attitudes regarding teaching of integrated STEM-related subject, Thibaout, Knipprath, Dehaene, and Depaepe (2018) have developed a valid questionnaire in alignment with a theoretical framework encouraged by Van-Aalderen, Walma and Asma (2012). The finding of the validation research provided any evidence for a framework composing of three conditions, namely perceived control, cognition, and emotion. In the field of STEM education, the study on science teachers related to the attitudes is relatively limited.

The next aspect introduced is knowledge. The definition of knowledge also has a broad meaning. Not Surprising if many discussions of teacher knowledge, just how difficult it is to probe this aspect of teaching practice by a quantitative survey. Thomson (1998) defined the term of knowledge as many specific meanings. Firstly, as familiarity or awareness obtained by an experience of a thing, person, or a fact, or as a person's range of any information. Secondly, as a practical or theoretical understanding of a language, subject, etc. or as an

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amount of what was known. Thirdly, a right justified belief; a specific understanding as opposed to a perception or opinion. Furthermore, Shulman (1986) divided teacher knowledge into three forms: propositional knowledge, case knowledge, and strategic knowledge. In the process of acquiring such knowledge, Biggam (2001) argued that there are many ways to gain knowledge. It could be obtained through some experiences. Moreover, knowledge could also be obtained from rational thought. In addition, knowledge can also be more specialized or even expandable. Nowadays, information and communication technology greatly influences the way to communicate and work of a knowledge (Binckly et al., 2012). Thus, in this research, the researchers restricted the term teachers' STEM knowledge to all information held by a science teacher about STEM education regarding the extent of the term STEM. The knowledge weather STEM education is one kind of teaching method or not, as well as their knowledge of the way to apply STEM in the classroom, including the interconnectedness of one discipline with another. Koehler and Mishra (2009) said that the teacher needs to be knowledgeable in each discipline and understand how they interconnect with each other.

STEM teachers have content knowledge that includes the scientific method, evidence-based reasoning, principles of engineering design and constraints, and mathematical theories and constructs, and technology applications that support their content knowledge. However, pedagogy is also one important thing. Pedagogy is the knowledge of how students learn classroom management skills, lesson planning and assessment (Koehler & Mishra, 2009). The challenge is to have sufficient STEM content knowledge, and effective pedagogical knowledge to make the learning effective, challenging and engaging. Several previous studies attempted to measure the knowledge, such as Lam, Doverspike, Zhao, Zhe, and Menzemer (2008), have tried to extract insight information about STEM, especially among high- school students. They elicit information by surveys through workshops on the knowledge and beliefs of students and parents on STEM Education. Gosselin and Macklem-Hurst (2002) also surveyed to access the level of knowledge of students in high school. Nevertheless, information about STEM teacher knowledge is still very limited.

Furthermore, the term of application, practice, and implementation are words that have the same relative meaning. Those show the meaning of realization or performance of some activities. Meanwhile, the term of practice is a real implementation or the usedness of a belief, method, or idea, as opposed to related-theories toward the term. Then, the implementation is the process of putting a decision or plan into effect or execution. In this current research, the researchers would like to use the term application rather than two other words. The term application is more appropriately applied to describe the teacher's STEM performance in the classroom. Many researchers have addressed the application of STEM in the classroom, but few still discuss it from the teacher's point of view, especially on a quantitative application. Han, Yalvac, Capraro, and Capraro (2015), have studied using a qualitative case study approach regarding teachers' implementation and understanding of STEM-related activities. They stated that in applying STEM in the classroom the teacher should pay attention to the academic level of the students, and the teacher should prepare as best as possible and try hard. English (2016), Herschbach (2011), as well as Kelley and Knowles (2016) asserted that whilst the quantity of STEM education over countries is significantly increasing, however, still not much was known about methods or approaches for the application of STEM education instruction. Overall means that, to understand the current situation in the field, especially in STEM education, this instrument is strongly necessary.

Research Focus

Any limitation of the existing STEM survey instruments on some previous researches (El-Deghaidy & Mansour, 2015; Meng, Idris, Eu, & Daud, 2013; Vennix, Brok, & Takonis, 2016), regarding scope and purpose as well as the need of an appropriate tool to access the latest progress on STEM education were the concern to be addressed in this current research. Then, this research focused on the design and development of a valid instrument that is used to determine the general quantitative degree of attitude, knowledge, and application of STEM by science teachers. This instrument serves as an essential tool and reference for evaluating and understanding the general description of STEM progress. The AKA instrument enables users to obtain data and information on the development of STEM, and the problems and challenges faced by science teachers worldwide. The worthiness of the instrument is determined by: (1) how does the development process of AKA instrument, and (2) how does the validity of the AKA instrument.

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Methodology of Research

General Background

This research attempted to develop an instrument used to scrutinize the quantitative degree of STEM attitude, knowledge, and application among science teachers. This research is categorized as Research and Development (R & D). There were four phases to get the final instrument namely planning, construction, quantitative evaluation, and validation. The ultimate instrument was qualified as a survey instrument used to determine the general quantitative degree of attitude, knowledge, and application on STEM simultaneously by science teachers on the secondary school. The quality of the instrument was determined based on reliability and validity. The quantitative way by Statistical Package for the Social Sciences (SPSS) was done in term accessing the reliability, while the validity was determined by both quantitative (SPSS) and qualitative ways (analysis of experts' opinions). Data were collected from Indonesian science teachers of secondary schools in different provinces from February to April 2018.

Sample

Samples taken for this test pilot were 137 participants who are secondary school science teachers in Indonesia. Table 1 here, points out a demographic data of respondents. This demographic data comprised gender, education background, teaching experience, and specialization of teaching. The respondents were secondary school science teachers from eight provinces in Indonesia for validity and reliability testing. In terms of ethical concerns, the researcher ensured the confidentiality of the participated teachers' identities in the current research. The purpose of the research was explained as well in detail, and all the respondents were assured of the confidentiality of their responses. Furthermore, there is no coercion in the retrieval of data and could be interpreted as all participants sincerely filling out and involved in this research. The subjects of the teachers were Chemistry, Physics, Biology, and Integrated Science subject both on junior and senior high school.

Table 1. Statistics data of the respondents.

Variable	Category	Quantity	Percentage (%)
Gender	Male	51	37.22
	Female	86	62.78
Education	Bachelor	93	67.78
	Master	44	32.22
Teaching Experience	<10 Years	97	70.80
	>10 Years	40	29.20
Area of Specialization	Integrated Science	51	37.22
	Biology	52	38.00
	Physics	18	13.13
	Chemistry	16	11.65

Procedure

There were four phases used in the design and development of this instrument. These phases were bypassed in order to obtain accurate instruments in measuring target variables (Creswell, 2005). Those four phases are planning, construction, quantitative evaluation, and validation. The four stages of the research are shown in Figure 1.

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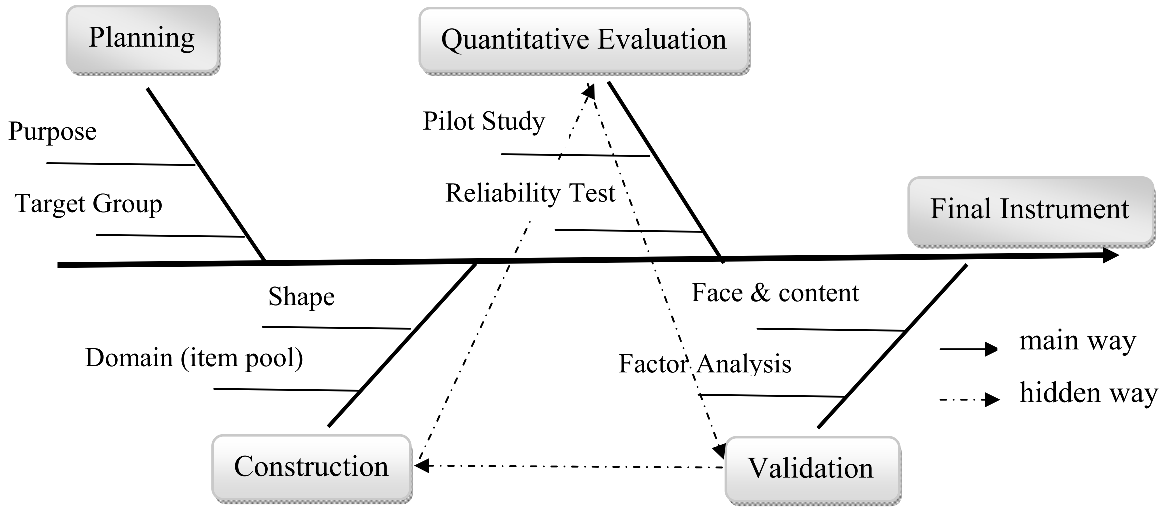

Figure 1. Research Phases of developing AKA instrument (adapted from Creswell, 2005).

The first phase was planning. At this stage, determining the purpose of making the instrument as well as the target group to be tested, were the main focus. As the researchers discussed before, the aim was to provide a basic tool and reference for evaluating and understanding the general description of STEM progress. The second stage was the construction stage. On this step, the researchers determined the shape of the survey instrument, identified the use of a 5-point Likert-type scale, divided the STEM domain into four sections and created items about each domain (item pool) and other additional issues to strengthen the survey results. The third stage was to determine and conduct a pilot study to obtain information about the deficiencies of the instrument made based on feedback from the respondent. The last stage was validation. The validation was conducted using face and content validation by experts as well as by exploratory factor analysis using SPSS. Actually, the quantitative phase and validation phase were performed simultaneously, and the result of this step would go back to the construction phase. The cycles did not finish until the researchers got the final instrument (hidden way). In the result of the research below, the researchers in detail provided what already had done in each phase, especially for the second to the fourth phase.

Data Analysis

In terms of to know the internal consistency in each domain created in the pilot study, the researchers used the reliability of the instrument. The internal consistency of the instrument was known from the value of the Cronbach's Alphas. Three main domains and five subdomains were accessed using this test. The domains were STEM attitude, STEM knowledge, and STEM application. The subdomains were STEM Science-Technology, Science-Engineering, Science-Mathematics, Science-Technology-Engineering, Science-Technology-Math, Science-Engineering-Math, and Science-Technology-Engineering-Math. Then, the next step was validation. In the validation phase, there were two types of validation done. The first validation of the instrument was assessed by three experts who are as content and face instrument validators. Those experts have experience in the development of an instrument and also know about STEM Education. Two of them are professors, and another one is a doctor in the science education area. They were using a 5-point Likert-type scale with a range of one to five to get their level of agreement. From the validation the results obtained the degree of approval from the validators as well as some suggestions and input. Feedback from validation was used to improve the research instrument for the better. The second validation was to perform exploratory factor analysis using the SPSS for windows version 22 that was by analyzing the loading factor of each domain item instrument.

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Results of Research

Development of Domain and Item Pool

The results of this development, the researchers titled "Survey of Science Teachers' Attitude, Knowledge, and Application (AKA) of STEM." The development of this instrument began with STEM domain grouping into three main groups, namely STEM knowledge (SK), STEM Application (SAp), and STEM Attitude (SAt). STEM knowledge was a domain that reveals the element of knowledge of respondents to STEM education. The second domain was the STEM Application. In this domain, these questions lead to information about the extent to which STEM applications were in the classroom by teachers of science teachers. STEM application was derived into several other small parts of STEM Science-Technology (SAp-ST), Science-Engineering (SAp-SE), Science-Mathematics (SAp-SM), Science-Technology-Engineering (SAp-STE), Science-Technology-Math (SAp-STM), Science-Engineering-Math (SAp-SEM), and Science-Technology-Engineering-Math (SAp-STEM). The last domain was a STEM Attitude (SAt). The SAt explores the information about attitude or respondents' view towards STEM education.

The STEM knowledge domain consisted of four question items that were representative of a single construct. In the beginning, we developed six questions, however, finally after reliability and validity test, they became four. The STEM application domain consisted of 23 question items consisting of six constructs. The 23 items were also the result after the reliability and validity test. While the last domain, STEM attitude consisted of three question items that were part of a construct. The final question items and each construct are shown in an appendix.

Reliability of Instrument

The analysis of instrument reliability level was done after obtaining data of the respondents' test results using Cronbach's Alpha method. Reliability test is an index showing the extent to which measurement tools can be trusted or relied upon. Below (Table 2), shows a resume of the reliability test results of the instrument.

Table 2. Reliability of the instrument.

STEM Domain	Internal Consistency (alpha)
STEM Knowledge (SK)	.908
STEM Application (SAp)	
Science-Technology (SAp-ST)	.819
Science-Engineering (SAp-SE)	.792
Science-Math (SAp-SM)	.811
Science-Technology-Engineering (SAp-STE)	.793
Science-Technology-Math (SAp-STM)	.724
Science-Engineering-Math (SAp-SEM)	.684
Science-Technology-Engineering-Math (SAp-STEM)	.865
STEM Attitude (SAt)	.866

Table 2 above shows that the value of internal consistency alpha of all STEM domains was greater than .6. The highest internal value of the highest three domains was in the domain SK (.908) and the lowest value is in the SAp domain (.865). As for fractions of STEM application, the highest value was at SAp-STEM (.865) and the lowest in SAp-SEM domain (.684). These values mean that the scale reliability of Cronbach's alpha was similar to with values greater than .6 considered acceptable. Therefore, the AKA instrument was to be acceptable of internal consistency among domains.

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Validity of Instrument

Development of the survey instrument was then validated to provide confidence, whether the instrument was feasible to use to obtain the right data or not. This research used two types of validation. The first, content and face validity was done using a 5-point Likert-type scale by three experts. This validity was conducted to see how the instrument looks like or appearance. Table 3 shows the results of the content and face validity, which concludes how much expert-approved or agreed on the presence and content of the instrument. Moreover, this validity was done to determine the readability, accuracy, and suitability of the instrument content. As a part of this validity, the experts gave some suggestions and comments as well. Second, the validation was verified by doing an exploratory factor analysis (EFA). There were some reasons why the researchers were doing EFA. Firstly, there was a set of underlying variables called factors that for aggregation of observed variables could indicate the interrelationships among those variables. Secondly, the authors want to know whether these items hang or swing together to create a construct. Finally, the authors want to know whether the questions in the survey had similar patterns of responses.

Table 3. Content and face validity.

No	Criteria	Validation Score			
		Expert 1	Expert 2	Expert 3	Mean±SD
1	Systematic preparation of instruments	5	5	4	5±0
2	Clarity and legibility of every item in the sentence	4	4	4	3.5±.7
3	Coherence between items within each domain	4	4	3	4±0
4	Completeness of items based on the purpose of developing the instrument	4	4	4	4±0
5	The accuracy of all items in measuring knowledge, attitude and ap-plication of STEM	4	3	4	3.5±.7
6	Ease of use	5	5	4	5±0
7	Scores obtained from the survey will illustrate the real conditions	4	3	4	3.5±.7
8	Does not contain SARA (racial, ethnic, and religious issues), violate intellectual property, pornography and bias (gender, territory, etc.)	5	5	5	5±0
	Total	35	33	32	35±1.4
	Percentage of validity	87.5%	82.5%	80%	83.33%

Note: Scale is 1 to 5; The framework validity is adopted and modified from Burton & Mazerolle (2011) and BSNP (2016).

The result was that the average expert agreement rate is 83.33%. Based on BSNP (2016), the agreement scores from the experts is 83.33% in the good level. No criteria items scaled below three, which means that all experts agree on the form and content of the instrument. However, experts still provided some notes and comments to refine the instrument. The experts' notes and comments are summarized in table 4 below.

Table 4. Comments, expert advices and improvements.

Domain		Comments	Improvements
Identities/ Demog-raphy	Expert 1	Please insert the aim of research in the questionnaire	Write down the aim of the research on the introduc-tion of this questionnaire
	Expert 2	It is better not use "name", but initials only	Change the item name to *an initial name*
STEM Knowledge	Expert 1	I often see my friends doing STEM class, this item should be removed because it will make the respondent confused	Removed
	Expert 3	I know everything about STEM	I *know* the term of STEM

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Domain		Comments	Improvements
STEM Application	Expert 1	Please give some examples of term the design something on the SAp-SE item	I often ask students to design something related to the topic of science (ex: *design replica of DNA, atom, etc.*)
	Expert 2	The meaning of technology not only as a tool, but also as a system of thinking in producing something	My students are actively involved using simple technology or a *particular procedure to produce something* in learning
		The number of items for SAp-STEM is too much unbalanced with other domains	Reduce the number of items from five to *four* items
		Give an example for this item, I often invite students to use all possible technologies to collect data on learning in the science classroom	I often invite students to use all possible technologies to collect data on learning in the science classroom (*ex: using a thermometer and use mathematical computation to make a decision*)
STEM Attitude	Expert 3	The two items are too few, add at least one more	Added one item "*I am very interested to know more how to properly integrate the mathematical, technological and engineering approaches in teaching science in the classroom*"
Complementary	Expert 2	The sentence structure of the item "Based on your knowledge, provide some of the possible difficulties... is not appropriate for the respondent, please add the word "current and ability"	Fixed the sentence structure and added word current and ability. *Based on your current knowledge and abilities, provide some of the possible difficulties*

Sentences or words in italic words are the result of a change

Those notes from the experts became valuable advice for researchers. Well known that what some people thought is good, may be different from what others think. Therefore, here, the role of experts was needed. However, some notes are not included in the table because researchers had a difference in understanding, but the numbers are very limited. For example, one of the comments is not to use the word "always" in the survey sentences. After carefully considering and relying on the original goal, the researchers ignored the note. Thus, after revising and accommodating the comments and suggestions from these experts, the progress of the instruments improved.

In addition to the face and content validation by experts, the researchers also performed a construct validation using exploratory factor analysis method. In terms of the construct validity, explanatory factor analysis was performed by using the IBM SPSS 22.0 for windows program. Based on Hair, Black, Babin, Anderson, and Tatham (2006), only any factors with an eigenvalue higher than one were included as representative. Then, Keiser-Meyer-Olkin (KMO) of sampling adequacy test .822 indicating that the variables are highly factorable (Table 4). The result of Bartlett's Test of Sphericity is significant ($p < .05$). The finding indicates that variables were correlated. The Bartlett test was statistically significant, then based on Pallant (2005), the value of KMO found is higher than the recommended value of .60, and that means the researchers continued the factor analysis.

Table 4. Sampling adequacy test.

KMO Measure of sampling adequacy		.822
Bartlett's Test of Sphericity	Approx. Chi-Square	996.724
	df	55
	Sig. (p)	.0001

Analysis result of a construct validation using exploratory factor analysis method shows three factors as shown in table 5 below. From the analysis, results obtained information that all items have a factor loading score higher than .5. However, one of the items (SAP_STEM4) gets a not-so-good value of .65, but the value is still eligible to include the item into the analysis.

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Table 5. Cronbach's α and factor loading for the main domain of STEM.

Items	Factor I	Factor II	Factor III
SK, α value =0.90			
SK1	.90		
SK2	.91		
SK3	.89		
SK4	.75		
SAP, α value =0.86			
SAP_STEM1		.83	
SAP_STEM2		.88	
SAP_STEM3		.84	
SAP_STEM4		.65	
SAt, α value =0.86			
SAt1			.88
SAt2			.86
SAt3			.83
Percentage of Variance	45.54%	18.10%	14.09%

Total variance explained = 77.74%

The largest percentage of variance is in factor one, which is 45.54% of the total variance explained about 77.74%. Finally, using principal component analysis with Varimax Rotation Method items SK1, SK2, SK3, and SK4 were shown to belong to Factor 1 as the values are larger than .3. Item SAP_STEM1, SAP_STEM 2, SAP_STEM3 and SAP_STEM4 belong to Factor 2. Then, items SAt1, SAt2 and SAt3 belong to Factor 3. Factor 1 refers to STEM knowledge, factor 2 refers to STEM application and factor 3 refers to STEM Attitude.

Final Instrument

The final instrument was the result after several revisions based on expert input and statistical analysis from the pilot study. The instrument consisted of three parts: the introduction, the core questionnaire items, and additional or complementary questionnaire items. The introductory section contained any matters relating to the purpose of making the instrument, how to use the instrument, how to provide and calculate survey scores and instructions for how to obtain data easily. For instance, *how do you score the survey? Each item response is scored with a value of one assigned to strongly disagree, all the way to five for strongly agree. For each construct, the participant's responses are averaged. For example, the four questions under SK (STEM Knowledge) are averaged to produce one SK (STEM Knowledge) Score*.

The core questionnaire item consisted of items to access respondents' demographic data totaling eight questions and the items to elicit teachers' AKA regarding STEM education. The example item to access respondents' demographic data was about "*the range of teachers' teaching experience (< 10 Years or > 10 Years)*". Then, the items to explore STEM knowledge, attitude, and applications totaling 30 questions. The example item to get information about teachers' STEM attitude was "*I strongly agree to implement the mathematical, technological and engineering approaches in teaching science in the classroom.*" Next, an example item to elicit information about teachers' STEM knowledge was "*I know the term of STEM*." Finally, the sample item to get information regarding STEM application was "*I usually teach science content using any kinds of technologies, engineering and mathematical context simultaneously*."

While the last part consisted of questions to access the application model of STEM and two open questions about opinions and obstacles or challenges of the implementation of STEM. For instance, "*based on your current knowledge and abilities, please provide some of the possible difficulties that will be faced when applying the integration of mathematical, engineering, and technology approaches in science classroom learning!*" The full form of core items regarding STEM knowledge, attitude and application by science teachers of the final instrument is shown in the appendix of this paper.

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Discussion

Exploratory factor analysis indicated that a three-factor was formed namely STEM knowledge, STEM application, and STEM attitude, which was calculated from 77.74% of the total variance. The analyses of the result showed that a sum of items loaded into factors that corresponded to the theoretical structure. Cronbach's alpha value of each domain or construct was all over .60. Important to note that Cronbach's alpha was evaluated similarly to scale reliability with values between .7 and .9 considered good. Then, the Cronbach's alpha values higher than .6, however, considered acceptable. Dillon and Goldstein (1984) and Joreskog (1971) asserted that the scale reliability also referred to as construct of reliability, was measured based on results of the exploratory factor analysis.

In addition, the distinguishment between this development process and previous similar process of developing an instrument is the content and face validation of the experts to elicit their approval or agreement. Dorrusen, Lenz, and Blavoukos (2005) said that researchers are necessary to assess the reliability and validity of the information provided by some interviewees in surveying research and expert interviews. Furthermore, they claim that inter-expert agreement is fundamental in the validation process of a new instrument. The result of the validity of the face and content performed by the expert showed the average approval value of 85%. Based on the analysis results of the factors and the expert agreement indicated that the developed instrument was reliable and valid, it is feasible to be used to collect data. However, any researches or replicated researches are still necessary to make this instrument more meaningful. Lin and Tsai (2017) suggested that replicated studies with national random samples may be meaningful in consolidating the findings of a study.

In terms of the item's context in this AKA instrument, the authors referred to several definitions that have been raised by previous research studies. An item related to STEM knowledge, for example, was "*I know the term of STEM*." Based on Thomson (1998), this item belonged to the category of knowledge that originates from a person's awareness or familiarity with something or a condition. Surely, in this case, was the awareness of the STEM education knowledge. Next one, the example item to get information about teachers' STEM attitude was "*I strongly agree to implement the mathematical, technological and engineering approaches in teaching science in the classroom*." The item could be classified into a statement that was predicted to explore information regarding person's attitude due to it was related to feelings of like or dislike, agree or disagree about a condition (Pryor, Pryor, & Kang, 2016), in this case, of course, again is related to the STEM education. Finally, an example item on the STEM application domain, e.g., "*I usually teach science content using any kinds of technologies, engineering and mathematical context simultaneously*." Authors argue that the sentence could extract information about teacher's STEM performance or activity in the classroom. This argument is under the definition from Thomson (1998) which stated that the application is an action of implementation of something on a surface. Thus, all items contained in AKA's instrument were relevant, valid, and feasible concerning its construct and definition to be used in assessing some important aspect on science teacher regarding STEM education in the field.

Teachers are a vital component in an educational process. Ibrahim and Aulls (2017) found that teachers' roles in class included the teachers' roles as motivators and facilitators as well as teachers' roles as mentors and models. Furthermore, the part of the teacher in STEM teaching and learning approach is to aid the students to develop a conception or abstractions and to decontextualize concepts for implementation in a variety of authentic contexts on different real-world problems (Moore et al. (2014). Thus, knowledge of STEM is absolutely required by science teachers. Quantitative knowledge can aid teachers towards better understanding and attitude. A good attitude led an impact on STEM application in everyday teaching and learning process. Various studies have proven that STEM applications by teachers are affected by several attributes such as the level of knowledge and attitudes of teachers themselves (Han, Yalvac, Capraro, & Capraro, 2015; Thibaut, Knipprath, Dehaene, & Depaepe, 2018). On the other hand, STEM is becoming a trend lately because of its reliability and potential in improving the quality of learning. However, not all the teachers understand and accept STEM. Many teachers were indicated to have misunderstandings and misconceptions toward STEM education. For instance, teachers show weak control of students and sometimes just sit down and see what students are doing without any intervening (Han, Yalvac, Capraro, & Capraro, 2015). Inevitably, an investigation or survey of the STEM attitude, knowledge, and application of the teacher becomes very important in providing information on current conditions and for better planning in the future. WHO (2008) states that the survey would be a tool to gather information about specific information or a specific small topic. Thus, they also suggested that the results of investigation through a survey could be a baseline to represent data collected, at a point in time before any intervention is carried out.

Then, some contributions of this current research to the literature. Firstly, this instrument is specially used to assess a general quantitative degree regarding attitude, knowledge, and application of STEM education simultane-

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ously by science teachers. Secondly, this research used factor analysis and content and face validity from experts to determine AKA's instrument validity which is the step rarely funded in some similar instrument developments. Then, the final results of the AKA instrument gave us a quantitative way to measure the progress of STEM Education.

Conclusions

The results showed that the designed and developed AKA instrument was valid and could be used to collect data. The AKA instrument allows for collecting quantitative data on a large-scale; and by using an amalgamated instrument, the field now has, a baseline to start from, or refer to, for any interventions of STEM education. The development of AKA instrument enables users worldwide to obtain information about the progress of STEM education and the problems as well as any challenges which would face the science teachers in the field. Furthermore, this instrument was being a prototype for the emergence of other similar instruments that may differ in some respects depending on the purpose of the development and where the instrument is used. Some of the things mentioned above reflect the limitations of this instrument. For instance, the purpose of this instrument was to know the general quantitative level of STEM, so it is unsuitable for data collecting from a STEM workshop' pre-test and post-test or other similar activities. Another limitation is that this instrument has only been tested in one country namely Indonesia. Then, in the next future research, larger samples from different area and cultures should be explored. It will take several repetitions, especially in different target countries to obtain more accurate results. However, a recommendation for further research is to test the psychometric properties of the instrument on a variety of cultural contexts and demographic data of the targeted respondents. Nonetheless, researchers believed that the AKA instrument could be used for researchers that are interested in, for instance, to explore some factors which affect science teachers to integrate STEM in their classroom on any areas or countries.

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Appendix

Table 1. Items in the final instrument

Items	Scales				
	Strongly disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Attitude Toward STEM Education (SAt)					
• I strongly agree to implement the mathematical, technological and engineering approaches in teaching science in the classroom					
• I am sure, students will gain more values if I integrate mathematical, technological and engineering approaches in teaching science in the classroom					
• I am very interested to know more how to apply the mathematical, technological and engineering approaches simultaneously and properly in teaching science in the classroom					
STEM Knowledge (SK)					
• I know the term of STEM					
• I aware that STEM in education is no kind of teaching method					
• I have enough knowledge about weaknesses and advantages of integrated STEM					
• I am convinced that STEM compile of integrated science, technology, engineering and math or compile of at least two of those disciplines.					
Application (SAp)					
Application of Science-Technology (SAp-ST)					
• I often teach a science subject with a variety of electronic tools					
• My students are actively involved using simple technology or a particular procedure to produce something in learning					
• Sometimes, I teach by asking students to use the internet in the classroom					
• I use a ready-made technology tool (not made by myself)					
Application of Science-Engineering (SAp-SE)					
• As a science teacher, in one term, I make learning media by myself					
• I often ask students to design something related to the topic of science (ex: design replica of DNA, atom, etc.)					
• I always create questions or assignments related to the students' ability to design and create a concept or model in the form of project tasks					
Application of Science-Math (SAp-SM)					
• Sometimes, I ask students to collect observational data on a science class in the form of numbers (quantitative data)					
• In science learning that produces data, I always lead the students to be analyzed using simple statistics					
• I often invite students to think carefully with mathematical thinking to make a decision					
Application of Science-Technology-Engineering (SAp-STE)					
• Sometimes, I design and make my own a simple technology or using a procedure to produce something that can be used in learning (ex: design and make a lever tool, measuring instruments, etc.)					
• In science learning in the classroom, I often ask the students to design and create any simple tools or models					
• Using engineering and technological context to explain more about the particular science topic					

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Application of Science-Technology-Math (SAp-STM)				
• In my class, I usually use a technology tool to mathematically analyzing of data from observation (ex: use calculator, computer, mobile phone, ect)				
• I often invite students to use all possible technologies to collect data on learning in the science classroom (ex: using a thermometer and use mathematical computation to make a decision)				
• I often explain the lessons about complex calculations in the science classroom and show it by Power Point or other learning technologies				
Application of Science-Engineering-Math (SAp-SEM)				
• I often ask students to use or recycle the goods around to be more useful and economical value, especially for the learning process of science				
• In the learning or practicum, students often use the analysis of profitability, graphics, and spatial ability of space, especially in engineering or creating a particular model or academic product.				
• Although I am a science teacher, I always teach to make a work which is made by the students themselves and there is an element of mathematical calculation in the process				
Application of Science-Technology-Engineering-Math (SAp-STEM)				
• I usually teach science content using technology, engineering and mathematical context simultaneous				
• I train students using mathematical thinking, design of planning and also technological assistance to solve various problems in decision making on science learning				
• In one term, I prepare or ask students to bring simple materials to design a particular model, together to search for information through the website or following a particular procedure to produce something and calculate the appropriate form (maximum length, breadth ideal, etc. for the design)				
• I often combine by many ways the technology, design-engineering, and mathematics approaches into a single learning topic of science				
Model of the Application	**< 25%**	**26-50%**	**51-75%**	**76-100%**
• In general, what percentage of you teach using technology tools, designing technology or designing certain concepts with students and analyzing mathematically on science learning in the classroom?				
• In general, what percentage of you integrate the mathematical, technological and engineering approaches in teaching science in the classroom in each semester?				
Open-Question the Possibility of Difficulty	**Open-ended questions**			
• Please give your opinion on the integration of mathematical, engineering, and technological approach in a science learning process in the classroom!				
• Based on your current knowledge and abilities, please provide some of the possible difficulties that will be faced when applying the integration of mathematical, engineering, and technology approaches in science classroom learning!				

Noted: In the appendix cited above, these categories (SAt, SK, and etc.) were removed, so that participants were not oriented to the constructs when answering the survey questions.

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