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by Javier Carroquino, José-Luis Bernal-Agustín and Rodolfo Dufo-López

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by Bevo Wahono and Chun-Yen Chang

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Assessing Teacher's Attitude, Knowledge, and Application (AKA) on STEM: An Effort to Foster the Sustainable Development of STEM Education

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Abstract: This study focuses on assessing the growth of the latest developments of science, technology, engineering, and mathematics (STEM) as part of an effort to maintain the progress of STEM education. Assessment is necessary for every educational activity, including in the field of STEM education. However, there are limited comprehensive reports on the progress and development of STEM education inside individual Asian countries. An attempt to bring up the sustainable development of STEM education is conducted by using an exhaustive assessment. The assessment, within this study, includes three domains, namely attitudes, knowledge, and applications (AKA) regarding STEM education. The comparison of these three domains based on demographic data, teachers' difficulties perception, and its contribution to the sustainable development of STEM education is, likewise, discussed. This type of research is a mix of both qualitative and quantitative research methodology. The quantitative analysis method was performed to address the level position and the comparative value of the three domains. In comparison, the qualitative analysis method was employed to strengthen the quantitative result analysis, as well as to deal with the teachers' perception. Results show that science teachers have a very good attitude, a moderate-level category in the application, and a low-level category in knowledge regarding STEM education. Further, there are differences in knowledge and the application of STEM education, based on educational background and teaching experience of the teachers, yet there are no differences regarding teachers' attitudes. Other components are discussed in detail, such as the teacher's perception of STEM teaching difficulties. Providing challenges and opportunities for improving the quality of education in the future are discoursed. The results of this study suggest that knowledge and attitudes are fundamental domains for the proper implementation, as well as sustainability, of STEM education (especially in Indonesia).

Keywords: assessment; STEM education; science teachers; education for sustainable development

1. Introduction

In recent years, STEM (science, technology, engineering, and mathematics) has become a trending topic in various scientific educational publications [1–4]. Education for students in STEM has received increased attention over the past decade, with calls for both a greater emphasis on these fields and improvements in the quality of curricula and instruction [1,2]. A STEM education approach emphasizes a new way of teaching and learning that focuses on hands-on inquiry and open-ended exploration [2]. The approach allows students with diverse interests, abilities, and experiences to develop skills

they will need in the 21st century workforce (e.g., problem solving, creative thinking, collaborative teamwork, technology literacy). The initial idea of STEM education was introduced in the 1990s, in the United States [5]. Currently, STEM education is flourishing in Asian nations [3,4]. Indonesia is one of the countries that has begun introducing STEM education to spearhead education (namely to teachers, in schools).

Teachers have a primary role in an educational system [6]. Likewise, teachers are at the forefront of STEM implementation in all countries around the world [7,8], particularly teachers who teach science subjects. Research has shown the importance of science teaching in almost all education levels [9,10]. The researchers argued that the aim of science teaching is to prepare scientists and technologists needed for the development of research and innovation. The preparation is a foundation for the economic prosperity and welfare of an emerging economy, as well as the development of any nations, including Indonesia.

Various efforts have been made to improve the quality of science education in Indonesia [4,6]. Based on the average results of trends in international mathematics and science study (TIMSS), for the last seven years, Indonesia has ranked fifth, from the lowest [11]. The result of TIMSS 2011 in the field of science showed that the high order thinking skills of Indonesian students remain in the low category, which is under the international average score. An example effort was made to implement new STEM education approaches and innovations adopted from other various countries [6]. The efforts require a comprehensive and appropriate assessment to ensure these implementations run smoothly. Assessment is, likewise, useful in ensuring the sustainability of education and the development of a country's development [12]. This shows that an assessment plays a vital role in improving the educational system, curriculum, quality of teaching, and student learning. The shortcomings, as well as the advantages, of education implementation, such as STEM education, will be revealed.

Attitudes, knowledge, and application (AKA) are three important domains for educational assessment [13,14]. These three elements can provide comprehensive information, as well as an overview of what is happening in an educational system, including data related to STEM education. The present study was carried out to: i) determine the level(s) of attitude, knowledge, and application regarding STEM education in Asian countries, notably in Indonesia; ii) to compare those variables regarding demographic data; and iii) to obtain opinions about the difficulties faced by teachers incorporating STEM. The assessment of the current status of the development of STEM education, through these three domains, is an effort towards fostering the progress of STEM education.

1.1. The Importance of Assessment

Assessment is an integral part of education [15]. Likewise, the assessment of STEM education has a key role in the progress of education in a country. The main objective of assessment in the field of education is to improve the quality of education itself, both on a small scale (classroom) and on a large scale (national curriculum). In the context of STEM education, assessment is conducted to determine the spread, acceptance, and progress of STEM among academics, including teachers, researchers, and education policy makers [16]. Through assessment, limitations, obstacles, and even challenges from the implementation of the STEM will be made known. These major issues point to a serious challenge, notably for academics and governments, seeking to improve STEM education and thus improve the enrolment of students into STEM fields at both a secondary and tertiary education level [17].

The importance of assessment in the field of STEM education has influenced several researchers interested in exploring the relationship between assessment and STEM [18,19]. A hypnotized STEM assessment model has been developed, which aims to access some essential skills obtained by students in a STEM lesson [18]. This study also advocates integrated STEM assessment models to see if students can use the various STEM skills, as well as interdisciplinary knowledge. Another piece of research has developed an assessment model framework that can access the current position of STEM development in a particular region [19]. The researchers divided the development of STEM into four stages, namely

not yet ready to initiate regular STEM programming, initiating STEM programming, improving STEM programming, and expanding high-quality STEM programming. This analysis also shows the vital role of assessment in three cycles of continuous quality improvement of STEM education, where a cycle consists of assessment, planning, and implementation.

1.2. The Domain of Attitude, Knowledge, and Application of STEM

Since the term attitude has been defined in many ways [20], in this study, we cited various sources to clarify the meaning of these words to position this current research. Attitude can vary in strength and direction, from extremely favorable to extremely unfavorable, including any point in between. The term attitude is defined as the overall evaluation of an object on several dimensions (good/bad, pleasant/unpleasant) [20]. Another definition lists attitude as a positive, negative, or neutral feeling toward some object or behavior [21]. In this research, "attitude" indicates whether the science teacher agrees or disagrees with the implementation of STEM (in students' classroom learning), the teachers' sense of curiosity towards STEM, and the teachers' thinking and feelings about STEM. Within the field of integrated STEM education, research on teachers' attitudes, especially as related to personal factors and personal points of view, is relatively scarce [22]. Therefore, accessing teachers' attitude regarding STEM education is significant in this current research.

The next aspect introduced is knowledge. The definition of knowledge has a broad meaning. Not surprisingly, the definition makes it difficult to probe this aspect of teaching practice using a quantitative survey. For this study, teacher knowledge is divided into three forms: propositional knowledge, case knowledge, and strategic knowledge. First, propositional knowledge is defined as a statement with right or wrong [23]. When asking about the wisdom of practice, the accumulated lore of teaching experience, people tend to find such knowledge stored in the form of propositions. Examining the research on teaching and learning, as well as exploring the implications for practice, is typically examining the proposition knowledge. Case knowledge is a specific knowledge which is well-documented and richly describes events. Finally, strategic knowledge comes into play as the teacher confronts particular situations or problems, whether theoretical, practical, or moral, where principles collide and no simple solution is possible. Knowledge can be gained through experience, but this is not the only way one can acquire knowledge. Knowledge can also be achieved through rational thought [24].

Several previous studies attempted to measure knowledge. Insight into STEM has been studied, especially among high-school students [25]. The researchers have elicited information via surveys and through workshops, on the knowledge and beliefs of students and parents on STEM education. Nevertheless, information about STEM teacher knowledge is still very limited. Thus, in this study, we 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 focus of STEM learning, their knowledge of the way to apply STEM in the classroom, and the interconnectedness of one discipline with another. Assessments of these kinds of knowledge are vital to the development of STEM education.

The terms application, practice, and implementation are words that have the same relative meaning. All three show the meaning of realization or performance of an activity. An application means the application of general rules to particular cases or the action of applying something to a surface [26]. Meanwhile, practice is the actual application or use of an idea, belief, or method, as opposed to theories relating to the practice. Implementation is the process of putting a decision or plan into effect or execution. In this current study, we prefer to use the term application rather than the other two words. The term application is more appropriately applied to describe the teacher's STEM performance in the classroom. While the number of STEM education initiatives across countries is rapidly increasing, not much is known about approaches for the implementation of integrated STEM instruction [5,27,28]. Teachers' understanding and application of STEM activities were explored using a qualitative case study approach [29]. The results suggest that in applying STEM in the classroom, the teacher should: (1) pay attention to the academic level of the students; (2) prepare as best as possible; and (3) try hard to apply STEM learning.

Those three domains (attitude, knowledge, and application) have an opportunity that is closely related to each other [30]. There is no such exception in evaluating the progress and development of STEM education through the creation of comprehensive evaluation tools. People who have knowledge of STEM, for example, will also have their attitude or views on STEM and may have a kind of positive or negative point of view [30]. Another piece of research asserted that the correlation between knowledge and attitudes had been the source of controversy in research on the public understanding of science [31]. A further study stated that sometimes there is a gap, between knowing and doing in the observed classrooms [32]. Said research indicates the importance of assessing everything, especially for something new, such as the emersion of STEM education in Indonesia.

1.3. Education for Sustainable Development

A prevailing opinion mentions that the lives of future generations are entirely determined by the present generation. Therefore, when serving the needs of the current generation, we must consider the sustainability of life for future generations. Education plays an important role in this position. Education is considered to be the central element of sustainable development [33]. Hence, there must always be an effort to improve, evaluate, or even develop existing education, includin applying and assessing the application and development of STEM education. Education is critical for promoting sustainable development and improving the capacity of people to address environmental and development issues [34]. Therefore, the term education for sustainable development appeared.

Education for sustainable development (ESD) is a vision of education that seeks to balance human and economic well-being with cultural traditions, as well as respect for the Earth's natural resources [35]. ESD emphasizes aspects of learning that enhance the transition towards sustainability. These aspects include future education, citizenship education, education for a culture of peace, gender equality and respect for human rights, health education, education for protecting and managing natural resources, and education for sustainable consumption. All educational levels and domains are tasked with contributing to ESD [36], including STEM on science education in secondary schools. Notably, the contribution of science learning to ESD has already been proven [33]. The researchers assert that this is true for ESD and especially the concept of Gestalt, which focuses on specific skills and capabilities needed to decide and act in situations of uncertainty and complexity. Thus, the sustainability of STEM is vital for the future of the next generation.

1.4. The State of the Problem

In Indonesia, teachers have been shown to mainly obtain information about STEM education from other education experts who are in college [4]. The deployment of the information to teachers incorporates various methods, including lectures, conferences, workshops, printed and electronic media, and various social media. However, not much is known about the development of STEM in Indonesia since its introduction into the educational system of the country. A new reform curriculum in Indonesia, namely curriculum 2013, was implemented in 2013 [37]. One of the most significant changes in curriculum 2013 is the freedom of teachers to use many kinds of teaching approaches in their classroom. Therefore, questions arise, such as: have science teachers in secondary schools ever implemented STEM in a classroom? Or, are there teachers who have never heard the term of STEM Education? Another possibility is the teachers may have performed STEM, but do not know that they have implemented the STEM approach. Likely, the teachers may have applied subdomains of STEM, such as science-technology, science-math, or science-technology-engineering in their teaching and learning. In addition, there are still limited references that discuss the comparison of knowledge, attitudes, and STEM applications based on demographic data such as gender, educational background, and teaching experience. Finally, the points of view of teachers towards STEM-related opportunities, its application, and the possibility of challenges and problems to be faced by both those who already know about STEM and those who have never heard about STEM education, are relevant topics to explore for the future sustainability of STEM education.

1.5. Objectives of the Study

This study aims to assess the current status of the development of STEM education through the three domains as part of an effort to maintain the progress of STEM education in Indonesia. The focus of this research is to elicit information about the degree of attitudes, knowledge, and STEM applications by science teachers in secondary schools. The results of the study are expected to be the basis for further research on STEM education, as well as information for other countries that are currently implementing or planning to implement STEM education in the future. Our analysis seeks to answer the following questions:

(1) What is the level of attitude, knowledge, and application of STEM education in science teachers in Indonesia?
(2) Are there differences in attitude, knowledge, and application of STEM education based on gender, educational background, and teaching experience(s) of the teachers?
(3) What is the perception of the teachers regarding difficulties if, or, at the time of, implementing STEM Education?

2. Materials and Methods

2.1. General Background

This type of research is quantitative and qualitative mixed research conducted by the survey method. The quantitative analysis method was performed to address the level and conduct the comparative study of the three domains. In comparison, the qualitative analysis method was done to strengthen the quantitative result analysis, as well as to access the teachers' perception. This research was conducted to obtain the latest information about the condition and development of attitudes, knowledge, and application of STEM education by teachers who teach science subjects in Indonesia. The underlying factors of respondents' demographics were also accessed, including: gender, educational background, main subjects taught, and the length of teaching experience. The survey was conducted by employing an online version for two months using various methods, including social media such as Facebook, WhatsApp, and E-mail. Authors distributed questionnaires to closed groups, such as in the group of teachers and science educators, to ensure that all the respondents were science teachers. Finally, the method, namely quantitative and qualitative mixed research, was conducted to assess the comprehensive of the growth of the latest developments of STEM education as part of work fostering the progress of STEM education.

2.2. Sample

The sample of this research is comprised of teachers, who taught science subjects in junior and senior high schools, and who answered voluntarily. The science subjects included were Biology, Physics, Chemistry, and Integrated Science. The number of respondents involved was 137 teachers, consisting of 86 women and 51 men. Respondents were from eight different provinces from all over Indonesia. Specifically, the respondents were from rural (18.98%), suburban (37.96%), and urban (43.06%) school areas. Table 1, describes the demographic data of the respondents.

Table 1. Demographic statistics.

Variables	Category	Number	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
	Integrated Science	51	37.22
Area of Specialization	Biology	52	38.00
	Physics	18	13.13
	Chemistry	16	11.65

In terms of the verification of sampling adequacy, a Keiser-Meyer-Olkin (KMO) and Bartlett's test were performed. Only factors with an eigenvalue higher than one were included as representative [38]. The KMO sampling adequacy test score was 0.822, indicating that the variables were highly factorable. The result of Bartlett's Test of Sphericity was significant ($p < 0.05$). The finding indicates that the variables were correlated. The Bartlett test was statistically significant, and the value of KMO found was higher than the recommended value of 0.60, verifying that the sampling was adequate [39].

2.3. Instrument

A survey instrument known as AKA [14] was used to collect data in this current research, on the attitude, knowledge, and application of STEM. The items in the questionnaire were guided by the STEM education Quality Framework (STEM, 2011). The instrument was divided into three domains, namely the STEM Attitude (SAt), STEM Knowledge (SK) domain, and STEM Applications (SAp). STEM Applications (SAp) were divided into sub-domains consisting of Science-Technology (SAp-ST), Science-Engineering (SAp-SE), Science-Mathematic (SAp-SM), Science-Technology-Engineering (SAp-STE), Science-Technology-Mathematic (SAp-STM), Science-Engineering-Mathematic (SAp-SEM), and the application of Science-Technology-Engineering and Mathematics (SAp-STEM). The core questionnaire item consisted of items to access respondents' demographic data, totaling eight questions. Other items were included to investigate STEM attitude, knowledge, and applications, totaling 30 questions. The example item to elicit 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 get 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 simultaneous." The instrument used a five-point Likert-type scale.

The analysis of instrument reliability level was conducted after obtaining data from the respondent test result, using Cronbach's Alpha method. The reliability test is an index showing the extent to which measurement tools can be trusted or relied upon. Following are the values: SAt (0.866), SK (0.908), SAp-ST (0.819), SAp-SE (0.792), SAp-SM (0.811), SAp-STE (0.793), SAp-STM (0.724), SAp-SEM (0.684), and SAp-STEM (0.865). The Cronbach's alpha values of each domain or construct were all over 0.60. Note that scale reliability was evaluated similarly to Cronbach's alpha, with values greater than 0.6 considered acceptable, and values between 0.7 and 0.9 considered good. Scale reliability, also referred to as construct reliability, was estimated based on the EFA results [40].

Further, face and content validation were also carried out by three experts. The average expert agreement rate of the validation was 83.33%. This percentage means that the instrument is valid and suitable for data retrieval. In addition to the face and content validation by experts, the authors also performed construct validation using the exploratory factor analysis method. From the analysis, it was shown that all items have a factor loading value greater than 0.5. This value means that the items are representative. Finally, using principal component analysis with the Varimax Rotation Method, items

SK1, SK2, SK3, and SK4 were shown to belong to Factor 1, as the values are larger than 0.3. Items 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.

The authors also utilized two open-ended questions to explore the perception of teachers, especially in relation to teacher knowledge and application. A possible way to get reliable research results is to utilize various combinations of strategies and research approaches that can strengthen each other [41]. The answers from respondents were grouped into three categories: rational, neutral, and irrational group. The answers from respondents were sorted into the rational group when the responses indicated that the respondents realized what they did not know regarding STEM. Another possibility was that the respondents knew that they knew. For instance, the respondent said "I still have limited knowledge about STEM. Therefore, I cannot provide an appropriate reason." Answers were grouped into the neutral group when the respondents indicated that their answers may or may not be reasonable. Whether or not the answers are reasonable depends on the condition of any other case factors. For instance, the answer of one respondent was "STEM approach will be difficult to perform in the classroom because sometimes it is unsuitable with the teacher education background." This kind of answer can be plausible, but actually, as a teacher, this obstacle should be viewed as an opportunity in the teaching and learning process. Furthermore, the irrational group is the group whose answers indicated that the respondents did not know that they did not know. For example, "STEM education is difficult to conduct since my school is in the village." Therefore, the authors can say these instruments could prove that an assessment is an essential tool in maintaining the progress of STEM education.

2.4. Data Analysis

Data in this current research was collected from surveying results using the AKA instrument. The data used to address the level of attitude, knowledge, and application of STEM education were analyzed using a descriptive quantitative method (utilizing Exel for windows). Multiple t-tests, using a statistical package for the social sciences (SPSS) Version 22, were performed to ascertain whether there were differences in attitude, knowledge, and application of STEM education based on gender, educational background, and teaching experience of the teachers. Furthermore, the perception data regarding difficulties if, or, at the time of, implementing STEM education were analyzed qualitatively to identify specific patterns or characteristics that distinguish between the three kinds of group (rational, neutral, and irrational) of teachers' responses.

3. Results

3.1. Descriptive Data

The following are the results of the data analysis of the AKA domain. Figure 1 below shows descriptive data, which includes the minimum value, quarter 1 (Q1), median (Q2), quarter (Q3), maximum, average, and range of each STEM domain. This data was analyzed from the average of each survey item grouped into each domain. The five-point Likert scale utilized starts from the smallest value, one, to the highest, five, for each question item.
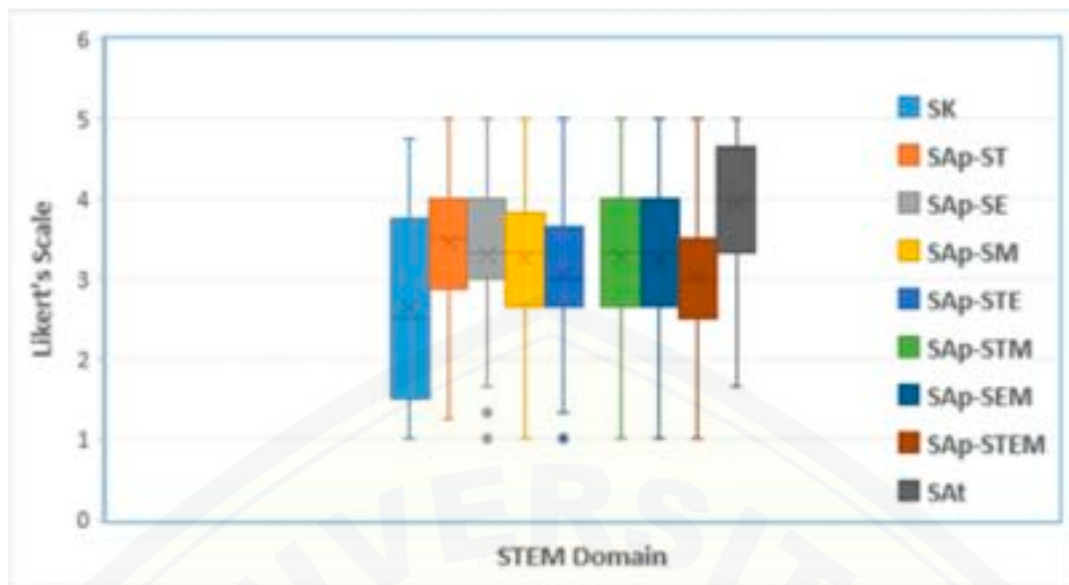
Figure 1. Descriptive data on each STEM Domain.

Figure 1 shows that the maximum value for the SK domains is 4.75, with an average value of 2.5, which is the lowest value compared to other STEM domains. Another interesting value is in the SAt domain. The minimum value (1.75) is the highest score if we compare the SAt domain to other domains (SK domain and SAp domain). The average value (3.94) of this domain also shows the highest score among other domains. Another thing that needs more attention is the value of SAp-ST. The value ranks show the highest in the STEM application domains, with an average of 3.45. The SAp-STEM domain, with an average value of 3.03, ranks the lowest of all domains owned by the application of STEM. Thus, overall, the domain of the STEM application was at the middle level when compared to the domain of STEM knowledge and STEM attitude.

Another interesting thing to note about the data in Figure 1 is that more than 50% of respondents are below the average in terms of knowledge about STEM education. However, on average, 50% of respondents have implemented STEM education in learning in the science classroom. More than 75% of respondents have a very good level of attitude towards the STEM education approach. The respondents have strongly agreed to integrate the mathematical, technological, and engineering approaches into teaching science in the classroom. Further, the respondents were sure that the students would gain more value if they integrated mathematical, technological, and engineering approaches into teaching science in the classroom. The respondents were very interested in properly integrating the mathematical, technological, and engineering approaches into teaching science.

Figure 2 below shows a distribution comparison of constructs. The construct of teachers' knowledge is represented by the respondent's knowledge of the STEM term, the attitude domain is represented by the beliefs of respondents when implementing STEM, and the application domain is represented by how many respondents have applied STEM in each of their classes.
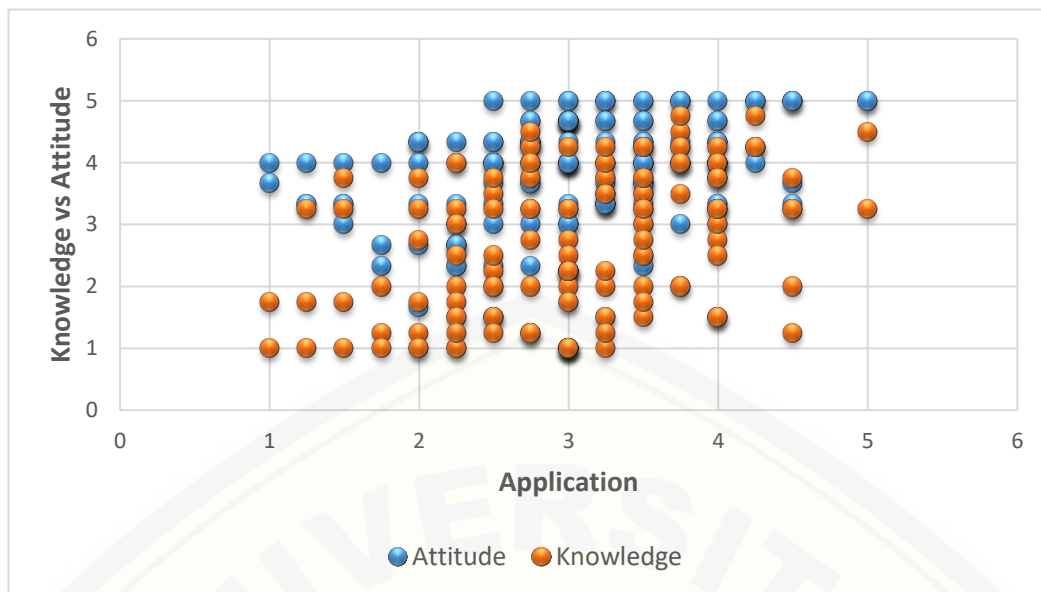
Figure 2. Distribution of frequency on five-point Likert scale regarding teachers' attitude, knowledge, and application of STEM.

Figure 2 reveals a striking difference in the concentration of data distribution. In the knowledge construct, most respondents answered with low-level scales, strongly disagree, disagree, and neither disagree or agree (1–3 Likert 'scale). In the construct of attitude concentration, data was listed at a higher-level scale, because respondents responded with neither disagree or agree, agree, and strongly agree (3–5 Likert 'scale). The concentration distribution of the construct of the application (the overlap color) was at the level of a neutral scale, namely disagree, neither disagree or agree, and agree (2–4). This form showed that, even though these science teachers have implemented STEM lessons in the classroom, these same teachers do not have a good knowledge about STEM education. However, the level of prior STEM implementation cannot be confirmed further in this current research. In addition, the data also showed the strong desire of science teachers to further explore STEM lessons, as well as their positive belief that STEM education will have a better impact on science learning. Those kinds of results presuppose the importance of evaluating STEM education as a matter to reflect on the next implementation steps or policies.

3.2. Comparison of STEM Attitude (SAt), STEM Knowledge (SK), and STEM Application (SAp) Based on Demographics' Data

This current research revealed several things, including the comparison of knowledge, attitude, and application of STEM. The following is data that show differences in the level of knowledge, attitudes, and STEM applications based on several factors. These factors are included in the data demography of the respondents. There were three factors emphasized in this research, namely gender, educational background, and teaching experience. The comparison of the three factors and the data demography of the respondents shows that there is a tendency or significance between them.

The results of the analysis show that there was no significant difference between knowledge, attitude, and STEM applications based on gender. However, the results show a tendency for men to have better attitudes, knowledge, and STEM applications compared to women. The results of the analysis, based on educational background and teaching experience, are shown in Table 2, below.

Table 2. Comparison of SK, Sat, and SAp based on their educational background and teaching experience.

Domain	Educational Background			Teaching Experience		
	Bachelor Degree (Mean $\pm$ SD), n = 93	Master Degree (Mean $\pm$ SD), n = 44	*p*-Value	<10 Years (Mean $\pm$ SD), n = 97	>10 Years (Mean $\pm$ SD), n = 40	*p*-Value
SK	2.255 $\pm$ 1.00	3.465 $\pm$ 0.95	0.000 *	2.866 $\pm$ 1.06	2.106 $\pm$ 1.15	0.000 *
SAt	3.795 $\pm$ 0.78	4.265 $\pm$ 0.64	0.001 *	3.955 $\pm$ 0.76	3.925 $\pm$ 0.79	0.836
SAp						
SAp-ST	3.225 $\pm$ 0.88	3.931 $\pm$ 0.76	0.000 *	3.561 $\pm$ 0.83	3.187 $\pm$ 1.02	0.028 *
SAp-SE	3.247 $\pm$ 0.84	3.409 $\pm$ 0.91	0.312	3.354 $\pm$ 0.80	3.166 $\pm$ 1.00	0.254
SAp-SM	3.172 $\pm$ 0.80	3.439 $\pm$ 0.88	0.081	3.271 $\pm$ 0.76	3.225 $\pm$ 0.99	0.769
SAp-STE	2.964 $\pm$ 0.80	3.250 $\pm$ 0.91	0.065	3.072 $\pm$ 0.85	3.016 $\pm$ 0.85	0.729
SAp-STM	3.060 $\pm$ 0.83	3.742 $\pm$ 0.90	0.000 *	3.250 $\pm$ 0.91	3.350 $\pm$ 0.91	0.565
SAp-SEM	3.132 $\pm$ 0.83	3.416 $\pm$ 0.85	0.067	3.295 $\pm$ 0.82	3.050 $\pm$ 0.87	0.123
SAp-STEM	2.948 $\pm$ 0.82	3.215 $\pm$ 0.86	0.083	3.103 $\pm$ 0.80	2.868 $\pm$ 0.91	0.139

Note: * $p < 0.05$.

In the STEM knowledge (SK) and STEM attitude (SAt) domains based on educational background, there were significant differences between teachers who have undergraduate and master's degrees. Teachers who have a master's degree possess better values of knowledge (3.465 $\pm$ 0.95) and attitudes (4.265 $\pm$ 0.64) towards STEM than teachers who have a bachelor's degree ($p < 0.05$). In addition to the application domain, teachers who have a master's degree also differ significantly in several areas, namely in the subdomain of the science-technology application (SAp-ST) and in the application of science-technology-mathematics (SAp-STM) ($p < 0.05$). In the other subdomains, including the application of science-technology-engineering-mathematics (SAp-STEM), there was no significant difference between teachers who have undergraduate and master's degrees ($p > 0.05$), even though the result shows a tendency for certain trends. The teachers who have master's degrees tend to have better value SAp-STEM (3.215 $\pm$ 0.86) than the teachers who have bachelor's degrees (2.948 $\pm$ 0.82).

There was a significant difference in knowledge between teachers who had less than ten years of teaching experience and teachers who had more than ten years of teaching experience ($p < 0.05$). Young teachers (<10 years) have a better value of knowledge (2.866 $\pm$ 1.06) about STEM than veteran teachers (>10 years) (2.106 $\pm$ 1.15). However, the result did not show a significant difference in their attitude domain. Based on teaching experience, there were significant differences in two subdomains, namely science-technology (ST) and science-mathematics (SM) ($p < 0.05$); in the application of these two subdomains, young teachers were better than veteran teachers. Therefore, the authors can say that the younger teachers and teachers who have a master's degree are potentially better agents of change, especially in the STEM education field.

3.3. Perception Regarding STEM Difficulties

Listed in Table 3 are some science teacher comments. We distinguished the teachers' comments into three groups. These groups are the rational group, the neutral group, and the irrational group. This division of groups was based on an analysis of teachers' responses to an open-ended question.

Table 3. Perceptions on the difficulties of implementing STEM.

Category		Comments	Percentage of Respondents (%)
Rational	(1)	Limited knowledge about STEM	27.45
	(2)	It is difficult to associate science topics with mathematics	
	(3)	Not all of topic can use this approach	
Neutral	(1)	Heterogeneous student abilities	30.58
	(2)	Student low on math skills	
	(3)	Teacher education background	
	(4)	Limited time	
	(5)	Limited access to technology	
Irrational	(1)	School position in the village	41.97
	(2)	Limited facilities and infrastructure	
	(3)	Students are not familiar to STEM	
	(4)	Low student motivation	
	(5)	There is no applications available for gadgets	
	(6)	Frequently failure of an electrical power supply	

Table 3 reveals that there were three groups regarding perception of the respondents. Some perceptions were classified as the rational group because the perceptions were plausible. For example, any opinions that had limited knowledge about STEM. This kind of perception is very reasonable. The perceptions indicate that the respondent knew that they did not know. Furthermore, the respondent knew that they knew regarding STEM. Thus, perceptions in the rational group are reasonable, especially for teachers who will apply or who have implemented the STEM approach. In this case, the respondents still need more knowledge, for example, a rational and philosophy behind STEM learning. The total number of this group (27.45%) is the smallest number of the two other groups.

Several other teachers were placed in a neutral group, which showed that the respondent had little knowledge of STEM. Teachers' knowledge was still at the surface level. That is to say, the respondents' answers were a little bit implausible. For instance, in this case, the background of teacher education does not support applying the STEM approach in the classroom. The teachers said, "STEM learning will be difficult to perform in the classroom because it is not suitable with the teacher education background." This kind of answer can be plausible, but as a teacher, this obstacle should be an opportunity to improve the teaching and learning process. Those perceptions in the neutral group can be a rational or irrational group. Sometimes, the educational background of teachers will be a problem when implementing a STEM approach, but sometimes it will be smooth.

Opinions were categorized as irrational because the respondents provided biased opinions regarding the difficulties when applying STEM. This condition is probably because respondents did not realize that they did not know about STEM. Finally, in the irrational group, an interesting example of the respondents' comments is "because of the position of the school in the village." This comment clearly shows that respondents did not realize that they did not know about STEM, but pretended they knew and understood the hows and whats of STEM education. Teaching STEM is not related to whether the school is in a village or city; instead, it is related to whether the teacher wants to or not. From the samples, this group has the most significant total number (41.97%). The largest number of the irrational group has a linear relationship with STEM knowledge (SK) of the respondents. Those kinds of teachers' perceptions, regarding the application of STEM education, indicate that an assessment has a vital role in formulating an appropriate implementation of STEM education for the future. We (as researchers, teachers, and policymakers) conclude that a majority of teachers still have a misperception regarding STEM education.

4. Discussion

The results of this research reveal some interesting facts to discuss. Bellow, the authors describe an astonishing finding, the diversity of STEM-related factors, and assessment as a tool to foster the sustainable development of STEM education.

4.1. An Astonishing Finding of STEM in Indonesia

The authors found an exciting finding of STEM education in Indonesia. A large number of respondents (more than 50% of respondents are below the total average of score) did not know much about or have never heard of the term STEM. This is an interesting finding of this research. The authors assume that some of the factors that caused this condition, include limited information regarding the development of education, limited internet access, limited facilities, and the vastness of the Indonesia territory. In fact, in Indonesia, there are still relatively few researchers, in higher education, involved in the field of STEM education [4]. The root causes of the low quality of knowledge and education of students, as well as teachers, in Indonesia are due to a combination of factors, including: low public spending on education, human-resource deficits, perverse incentive structures, the wide area, poor management, and the matters of politics [42]. Another potential reason is the low quality and quantity of professional development activities for teachers. In other research, teachers' professionalism and professional development practices in Indonesia have been investigated [10]. The results showed a condition that still indicated a lower quality and quantity and that improvements of the root causes did not produce an improved performance in teachers' professionalism or professional development practices in Indonesia [11,43].

Another interesting finding, from this study, was that, on average, almost 50% of respondents applied STEM lessons in their science classes. However, a condition was known that more than 65% of respondents had a low level of knowledge regarding STEM. The inverse relationship between a low level of knowledge and the application of STEM can be explained scientifically. The framework of the relationship of knowledge to action and application was analyzed. The framework mentioned that knowledge will lead the application, but sometimes the application does not have to be based on knowledge [13]. Using science disciplines, engineering, and technology-based learning, as well as emphasizing hands-on activities in the classroom, are some samples of the STEM principles. Thus, the authors found that even though the teachers did not know what the term STEM was before, whether consciously or unconsciously, the teachers had applied some principles of the STEM approach in a natural classroom setting.

Another finding of the current research is that although most teachers do not know what STEM is, more than 75% of teachers have a very good attitude towards STEM. This condition is also potentially the reason why teachers have implemented STEM, without knowing the term. However, the degree of STEM application has not been deeply confirmed in this research. The findings of attitude and knowledge indicate that these two domains are fundamental to the proper implementation, as well as sustainability, of STEM education.

4.2. Diversity of STEM-Related Factors

There are some factors potentially influencing the condition, growth, and sustainability of STEM education. The factors include: gender, educational background, teaching experience, perception, area of specialization, etc. However, in this current research, the authors only focused on the first four in the list.

The first factor that the authors discussed is gender. The resulting trend shows that male teachers have a better knowledge of STEM than female teachers, but there was no significant difference between the knowledge of male and female teachers in this research. This result makes sense because engagement, acknowledgment, or information regarding STEM could be received equally by both

males and females [44]. This situation is different from STEM knowledge and STEM attitude based on educational background.

There were significant differences in both STEM knowledge and attitude between teachers who have a bachelor's degree and those who have a master's degree. Science teachers who have master's degrees were assumed to have better knowledge (3.465) and attitudes (4.265) than the teachers who have bachelor's degrees (knowledge, 2.255; attitude, 3.795) due to several reasons. First, teachers with a master's degree have a higher level of education, which means that knowledge of educational innovations is more likely than those who only have a bachelor's degree. The fact that the majority of the teachers with master's degrees are fresh graduates and young people is another concern. There is a stereotype that fresh graduates and young people are more aggressive, more active, and more innovative than veteran people, especially in terms of technology and innovation. This reason is quite reasonable because one of the characteristics of youth is being aggressive and quickly absorbing change [45]. Mostly, good knowledge will lead to a good attitude. People who have good knowledge of something, especially if something is really good, will most likely have a good viewpoint or attitude. This argument is reasonable because the attitude is rooted in familiarity and awareness [46]. In addition, in the STEM applications domain, teachers who have a master's degree were also significantly different in several parts, namely in the subdomain of science-technology applications (SAp-ST) and in the STEM application of science-technology- mathematic (SAp-STM). A plausible reason why the teachers who have a master's degree performed well on the STEM application related to technology, is that the Indonesian ministry of education has strongly suggested using technology learning media in the master's degree classroom courses [47]. So, it is not surprising that the STEM application in these two subdomains differs significantly in the educational background aspect.

Another interesting finding in this research relates to the teaching experience factor. The veteran teachers actually have a lower value of knowledge (2.106) of STEM compared to novel teachers (2.866). The finding is very reasonable because the novel teacher, of course, brings the newest knowledge and developments, as well as educational innovations, from a university. In addition, novel teachers who are still young and energetic tend to update information about education from various sources, including social media, newspapers, websites, and others. Veteran teachers tend to stick with the knowledge which they already have and are thus not inclinded to upgrade their knowledge [48]. However, the difference in knowledge did not cause variations in the teachers' attitudes towards STEM. Both groups of teachers have very good attitudes towards STEM education. In addition, the implementation of STEM in the subdomain science-technology showed that science teachers who have shorter teaching experience tend to have better science-technology applications. Technology is identical to young people [45], as well as its use in class. Therefore, it is no wonder that the results of the analysis showed the novel teachers were better than the veteran teachers in the science-technology application.

In terms of perceptions, the excitement for discussion is 41.49% of respondents have irrational opinions regarding the questions. The possible difficulties that teachers would face if or when implementing STEM in the classroom was the question asked about. This percentage was closely related to the number of respondents who were low in knowledge of STEM; about 65% of respondents had a low knowledge about STEM education. Knowledge possessed influences the quality of opinions, such as rational, neutral, or even irrational. Opinions such as frequent failure of an electrical power supply, school position in the village, and there is no application provided on a gadget indicate the teachers' low level knowledge of STEM.

4.3. Assessment as a Tool to Foster Sustainable Development of STEM Education

The low category level of knowledge and moderate level for the application of science teachers regarding STEM education indicate that a lot of things must be managed to improve the usefulness of STEM education in Indonesia. Furthermore, based on the model of a quality STEM program pathway [19], this current result of research indicated that Indonesia is still in the initiating position

(from four positions: not yet ready, initiating, improving, and expanding). Perhaps, structured and massive professional development is one of the possible ways to improve this condition. Inevitably, however, STEM education that is powerful in shaping the younger generation for a career in the STEM field [49,50] has the potential to make development better in many fields. Moreover, the results of this research indicated that the teachers' (more than 75% of respondents) have a positive attitude towards STEM. Teachers' attitudes towards STEM activities were also investigated by another researcher, and the result showed that teachers have a positive attitude towards STEM [51]. Indeed, the positive attitude is an important factor in implementing STEM learning. These positive attitudes become a strong foundation as motivation to learn more, and at the same time, to apply STEM in each class.

Furthermore, from this current research, it was revealed that novel teachers had a better knowledge value of STEM (2.866) than veteran teachers (2.106). The novel or the young teachers, who still have extended teaching opportunities, are very supportive in the efforts to promote education. This condition certainly supports the development of a better educational system, economy, and welfare for future generations. Those developments for the future are highly determined by the condition of how the teachers teach the students in the classroom right now.

STEM as a learning approach is closely related to teachers and students. Regarding the purpose: to maintain the quality of teaching and learning, it is important to know about the assessment domains of attitude, knowledge, and application (AKA) in the field [14]. Assessment became a tool to realize the purpose. The main purpose of the assessment in education is to find out the extent of implementation, success, lack, and advantages of the application on education itself [15]. Indeed, assessment must focus on sustainability. The sustainability of STEM assessment is closely related to improving relationships between teacher(s) and students in the classroom [49].

Further, the sustainability of assessment plays a vital role in improving the educational system, curriculum, quality of teaching, and student learning [52,53]. Assessment reveals the shortcomings, as well as the advantages, of education implementation, including STEM education. Development of a country will run smoothly if education supports the development. Some components in education, such as citizenship education, education for a culture of peace, gender equality, and respect for human rights, as well as health education, are needed to support the development of a country. Therefore, the authors can say that what is done in education will effect the sustainability of development of a nation. The role of education is sustainable development [54]. The relationship between education and sustainable development revealed that the development of education in the context of sustainable development is not only the promotion of the answer to science, but also different perspectives on every facet of our lives. The authors want to show, with the results from this study, that a sustainable assessment (e.g., AKA assessment) is needed to escort the growth of STEM education in Indonesia.

5. Conclusions and Implications

5.1. Conclusions

This research aimed to assess the progress of the latest developments of STEM education through the three domains as part of the effort of maintaining the growth of STEM education—namely the degree of attitudes, knowledge, and applications (AKA) by science teachers. The focus of this current research was to grasp information about the degree of the AKA domain, differences regarding demographic data, teacher' perception, and the contribution of the assessment to the sustainable development of STEM education. According to research analysis, science teachers have a very good level of attitude, moderate level in application, and poor level of knowledge regarding STEM education in Indonesia. Additionally, there was a significant difference in the knowledge and application of STEM education based on educational background and teaching experience of the teachers. However, there was no significant difference in teachers' attitudes. Meanwhile, the authors also divided teachers' perception regarding the difficulties if, or at the time of, implementing STEM into three groups.

The groups were rational, neutral, and irrational. Finally, this current research showed that assessment can contribute as a tool to foster the sustainable development of STEM education.

5.2. Limitation and Academic Implications

The limited number of respondents is perhaps one of the weaknesses in this research. Then, larger samples from different cultures should be investigated in future research. To make the study more representative, the sample was taken from many kinds of places, such as rural, suburban, and urban schools from eight different provinces. However, several implications can be drawn from this research. Firstly, the application of STEM in science classes will be better if the teacher has enough knowledge and is strengthened by a good attitude towards STEM. Weak knowledge and a bad attitude meant that the STEM application in the classroom worked severely. Despite this, the application does not take place anymore. Those findings of attitude and knowledge indicate that these two domains are fundamental to the proper implementation, as well as sustainability, of STEM education.

Secondly, the lesson that can be taken is that an assessment will provide insight and information to all parties, especially policymakers in the field of education. The result will be a kind of scientific information. The scientific information will be a strong foundation in policy making, primarily to support industrial reform 4.0, in the term the field of education. One of the focuses of education, in the industrial era 4.0, is on mastering and internalizing technology and engineering for students who are suitable in STEM education. Sustainable and structured assessment is an absolute thing in the field of education because weaknesses and strengths will be clearly seen. Thus, the assessment of STEM education is a starting point in strengthening educational sustainability. In line with this, Agenda 21 states that education is an essential tool for achieving sustainable development [55].

Thirdly, the results showed the low level of knowledge and application of most science teachers. This situation is a reason to increase the amount and quality of professional development, especially in the field of STEM education. Furthermore, the positive attitude shown by the teachers makes a good starting point for quality professional development. The positive attitudes by teachers are employed to support educational innovations that are in line with the progress of the era and technology. Thus, encouragement of innovation in teaching practices is useful for improvement in personal and career fields for members of school communities [42].

Finally, this research will be a basis for carrying out further research in the field of STEM education and broader general education. In the STEM field, hopefully, other research will emerge that can strengthen the STEM application, develop curricula related to STEM, and assess more STEM learning. Those in the field of research have a role in fostering the sustainable development of STEM education for the future. In the field of education in general, this research provides information about the development and direction of future education research for the 21st century.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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