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Students' Attitudes towards STEM Education: Voices from Indonesian Junior High Schools

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ABSTRACT

The purpose of this study was to investigate Indonesian students' attitudes towards Science, Technology, Engineering and Mathematics (STEM) through survey study. Data collected from 260 Indonesian junior high school students (47.3% male and 52.7% female) who were studying at public school in East Java province. The Attitudes Towards Science, Technology, Engineering and Mathematics (AT-STEM) questionnaire was developed with Indonesian language and validated through an exploratory factor analysis of participants' responses. In addition, the Pearson product moment was used to measure the correlation among four dimensions of scale. The results indicated that, *first*, the instrument used in this study had satisfactory validity and reliability. The construct validities of the AT-STEM were varying from .60 and .96 and explained 86.84% of the variance. Overall, the Cronbach's alpha coefficient of the instrument was .94. *Second*, the dimension of Mathematics came in the first rank and followed by Science as well as the degree of attitudes towards STEM. *Last*, the results also showed a significant interrelationship among dimensions of attitudes towards STEM.

Keywords: Attitude; STEM; Indonesia; Student.

INTRODUCTION

Education approach for students in Science, Technology, Engineering and Mathematics (STEM) has received increasing attention over the past decade (Honey, Pearson & Schweingruber, 2014). The approach is greater emphasised on these fields for improvements in the quality of curricula and instruction. In other words, STEM is a curriculum based on the idea of educating students in four specific disciplines — science, technology, engineering and mathematics — in an interdisciplinary and applied approach. Rather than teaching the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world applications (Hom, 2014).

Several benefits of STEM education include making students become better problem solvers, self-reliant, innovators, inventors, creators, logical thinkers and technologically literate (Morrison, 2006). STEM stimulated students becoming critical thinkers. Some studies have shown that integrating mathematics and science has a positive impact on students' attitudes and interest in school (Bragow, Gragow & Smith, 1995), their motivation to learn (Gutherie, Wigfield & VonSecker, 2000) and achievement (Hurley, 2001). Recently, another study focused on an educational strategy based on professional practices can help students make connections between mathematics, statistics, science and professional practices (Dierdorp et al., 2014). Meanwhile, the study with integrating science and technology

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education by applying “robotic science” indicated that the use of technology in different disciplines will contribute to the nation (Koç & Böyük, 2013). Moreover, the National Academy of Engineering and the National Research Council list fifth benefits of incorporating engineering in K-12 schools: improved achievement in mathematics and science, increased awareness of engineering, understanding and being able to do engineering design, increased technological literacy and interest in pursuing engineering as a career (Katehi, Pearson & Feder, 2009).

Regarding the importance of synergies between science, technology, engineering and mathematics, then students need to be stimulated towards a positive attitude about them at the beginning. While, there has been considerable research conducted about students’ attitudes towards science (Osborne, Simon & Collins, 2003) and mathematics (McLeod, 1994), science and mathematics (Özgün-Koca & Şen, 2011), there is less research available about students’ attitudes towards technology and engineering. Various categorisations had been developed to capture the attitudes towards STEM which can usefully be applied to students (see, for example, Tyler-Wood, Knezek & Christensen, 2010; Tseng, Chang & Lou, 2011; Faber et al., 2013; Guzey, Harwell & Moore, 2014). However, most of the studies conducted in the US, Europe, Taiwan, Turkey and others and rarely heard from developing countries like Indonesia. As Faber et al (2013) reported that the United States remains a world leader in discovery and innovation today because of STEM education already widespread. Therefore, it is important for a country to improve their creativity and competitiveness through STEM education.

In particular, the concept of STEM in Indonesia became popular in recent years, especially in higher education level. It can be said that the concept is gradually developing in Indonesia. Some researches and events were turned to this concept, such as an innovation strategy to build students’ disaster literacy through STEM-D (Science, Technology, Engineering, Mathematics and Disaster) Education (Sampurno, Sari & Wijaya, 2015); a partnership program between local schools in Riau province and Honeywell about science and technology (Honeywell, 2014); and an ongoing project between Columbia University and the Institute Pertanian Bogor to improve the teaching of STEM in Indonesian high schools (Columbia Global, 2014). However, some of these programs were more emphasised on the secondary and higher education rather than the low levels of education, such as elementary and junior high school. Bottia et al (2013) also recommended that the feasible approaches for inspiring, reinforcing and preparing more of the nation’s youth to choose a STEM pathway for their futures. Therefore, this study focused on junior high school student for primary potential integrating STEM education.

Based on the introduction and the aforementioned theoretical foundations, the purpose of the current study is to investigate the Indonesian students’ attitudes towards STEM. To this end, the aims of this study were twofold:

1. To explore the degree of attitudes towards Science, Technology, Engineering and Mathematics among junior high school students in Indonesia.
2. To examine the interrelationships among dimensions of attitudes towards Science, Technology, Engineering and Mathematics.

METHODOLOGY

a) Research Design

Starting from July to August 2015, the author spread out the questionnaire by traditional survey method to students in three junior high schools in East Java province, Indonesia. Survey designs are procedures in quantitative research in which investigators administer a survey to a sample to describe the attitudes, the opinion, behaviors or characteristics of population (Creswell, 2012). Specifically, the survey is a useful tool to assess efficacy of STEM education programs on students' attitudes towards STEM and STEM careers (Guzey et al., 2014). Figure 1 depicts the process of survey design.

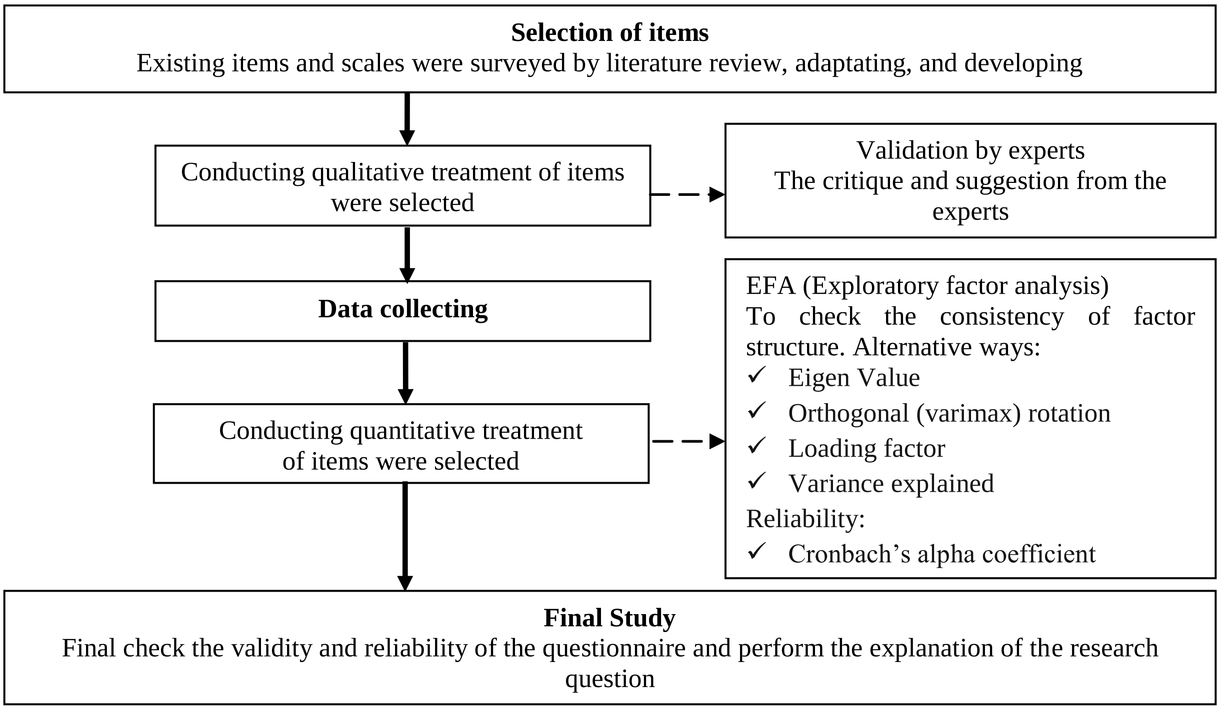

Figure 1. *The process of survey study*

b) Participants

As described in the introduction, this research focuses on the junior high school students. The participants were 260 junior high school students (aged 12–16 years) at public school in East Java Province, Indonesia. In this study, the participants consisted of 47.3% male and 52.7% female. The sample varied of demographic factors, as shown in Table 1.

Table 1. *Summary of sample demographics (N= 260)*

Background	Subtotal	
	n	%
Gender		
Male	123	47.31
Female	137	52.69
Grade		
Seventh (7)	83	31.9
Eight (8)	90	34.6
Nine (9)	86	33.1
Missing	1	0.4
Total	260	100.0

c) Instrument

The instrument used in this study was the Attitudes Towards STEM Questionnaire (AT-STEM). Derived from other attitudes questionnaires (such as Faber et al., 2013 and Guzey et al., 2014), this STEM attitudes questionnaire was examined by three experts. Originally, the instrument consisted of 27 items for AT-STEM, which used English version (see Appendix).

The instrument distributed into four crucial conceptions of STEM education, including Science (S), Mathematics (M), Technology and Engineering (T-E) and Science, Technology, Engineering and Mathematics (STEM). The items were coded on a five-point-Likert-type scale, ranging from 1 (strongly disagree) to 3 (neutral) to 5 (strongly agree). The higher scores indicated the greater attitude towards STEM education. By translating process into Indonesian and checking the content validity, the instrument feasible to Indonesian students. Two items with low factor loading were deleted and twenty-five items remained in the questionnaire. The information of validity and reliability for the scale is shown in Table 2.

d) Procedure

The data collection of this study was accomplished with printed surveys. Invitations were first distributed to the potential participants (i.e. Junior high school students in East Java Indonesia) through email, face to face requests and science teachers' assistance. This made sure that all the participants volunteered to take part in and to respond to the questionnaires. At the beginning of the surveys, the students were informed of the aim of this study and the purposes of the questionnaires. In the questionnaires, the author only addressed the intention to investigate students' perspectives and confidence about attitudes towards STEM education. However, the issue about STEM education was relatively new in Indonesia. Therefore, in the first step the researcher with supporting by three science teachers introduced and demonstrated teaching and learning process by integrating STEM education as a foundation for students' prior knowledge.

The Hydrogen fuel cell was used to integrate between formal science curricula and STEM education. The solar Hydrogen science kit guided students to invent their own clean energy applications using fuel cells and renewable hydrogen created using solar energy and water (see Figure 2). The set was equipped by a complete curriculum on renewable energy with easy experiment, manual kits and background history on the technology. The sub-topics of the experiment include: the effect of heat on solar panels, finding the solar panel's maximum power, electrolysis mode (generating Hydrogen and Oxygen from water) and fuel cell mode (generating electricity from Hydrogen and Oxygen).

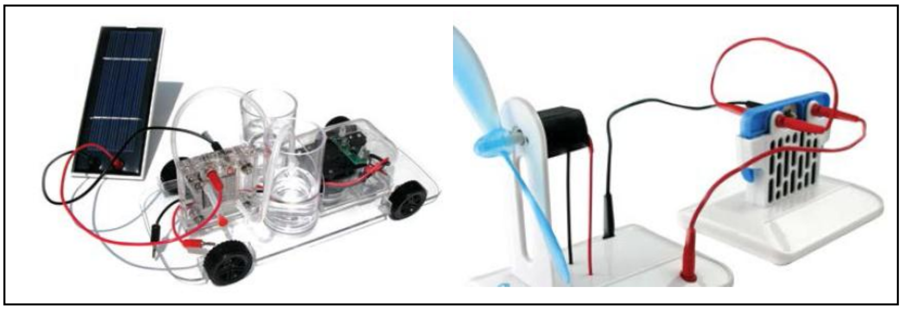

Figure 2. *The Solar Hydrogen Science Kit (Horizon Educational, 2015)*

e) Data Analysis

The Attitudes Towards STEM Questionnaire (AT-STEM) was developed with English version and translated into Indonesian language. The data analysis of this study was threefold. First, the author determined whether the data were appropriate to perform an Exploratory Factor Analysis (EFA) through Kaiser–Meyer– Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. Hereafter, analysis of data used SPSS's software for checking the validity and the reliability of instrument. According to the validation criteria of exploratory factor analysis suggested by Stevens (2002), the retained items should preferably be weighted greater than .4. In other words, the items with a factor loading less than .4 were deleted. The principal component extraction with orthogonal (varimax) rotation was conducted to estimate the number of factors proposed in this study, which contributed to the construct validity of each instrument. Furthermore, the Cronbach's alpha coefficient for each scale of the AT-STEM instrument was calculated to ensure the reliability of each factor as well as the overall alpha coefficients of the instrument. Second, the mean and standard deviation of each dimension was used to depict the degree of attitudes towards STEM. Third, the Pearson product moment was used to measure the correlation among four dimensions of AT-STEM.

FINDINGS

a) Exploratory Factor Analysis of AT-STEM

To validate the AT-STEM instrument, an exploratory factor analysis with a varimax rotation was performed to clarify its structure. Originally, from 27 items performed the Kaiser–Meyer– Olkin (KMO) value was .87 and the result of Bartlett's test was significant (X^2 = 12972.31, $p < .001$), indicating that the samples were appropriate for factor analysis. However, two items were deleted because these items with a factor loading of less than .4 (e.g. S3: Knowing science will help me earn a living and TE3: I am curious about how electronics work). A possible reason to explain these findings is students maybe confidence that science will be important in their life, but it doesn't necessarily help them earn a living. In addition, some students feel not too curious about how electronics work rather than what makes machines work and how imagine creating new products. It can be understood that the electronic materials (e.g. robotics, complex electrical circuit) are very minimal applied in the science curriculum in Indonesia. This situation is different with another study. Koç & Böyük (2013) who applied "robotic science" in Turkey found some contributions to science and the nation.

Hereinafter, the participants' responses were grouped into the following four proposed factors—(1) science, (2) mathematics, (3) technology and engineering, and (4) STEM—and a total of 25 items were retained in the AT-STEM instrument. The KMO value was .86 and the result of Bartlett's test was significant (X^2 = 12854.49, $p < .001$), indicating that the samples were appropriate for factor analysis. The detailed descriptions and sample items of the four dimensions are presented as follows:

1. Science (S, six items): exploring the students' attitudes towards science, such as science in school, out of school, and life's work, and a career in science.
2. Mathematics (M, seven items): exploring the students' attitudes towards mathematics, such as learning mathematics, grade and choosing career in mathematics.
3. Technology-Engineering (TE, five items): exploring the students' attitudes towards technology and engineering, such as using technology, new machine, creating new product and a career in engineering.
4. STEM (seven items): summarising the students' attitudes towards integrating science, technology, engineering and mathematics, such as using creativity and innovation for future work and a career that involves science, mathematics, engineering, or technology.

The eigenvalues of the four proposed factors from the principal component analysis were all larger than one, and the total variance explained was 86.84% (see Table 2), which was validated to clarify the structure of the instrument. The dimension of STEM itself can explain the highest variance with achieved 25.78%. It means the students' attitudes can be more explored from the combination of four terms together: science-technology-engineering-maths than each factor separately. Table 2 also shows factor loading of attitudes towards STEM education designed to measure each factor were between .60 and .96, so that it meets the criteria of Stevens (2002). In addition, the reliability in terms of Cronbach's alpha coefficients for these factors were .97, .93, .99, and .98, respectively, and the overall alpha value was .94, suggesting that these factors had high internal consistency for assessing the participants' four dimensions of attitudes towards STEM.

Table 2. *Rotated factor loadings and Cronbach's alpha of the AT-STEM questionnaire*

	Factor 1: S	Factor 2: M	Factor 3: TE	Factor 4: STEM
Factor 1: Science (S), α = .97, variance explained = 21.01%				
S1	.89			
S2	.91			
S4	.93			
S5	.93			
S6	.87			
S7	.89			
Factor 2: Mathematics (M), α = .93, variance explained = 20.53%				
M1		.92		
M2		.91		
M3		.60		
M4		.92		
M5		.85		
M6		.85		
M7		.64		
Factor 3: Technology-Engineering (TE), α = .99, variance explained = 19.52%				
TE1			.96	
TE2			.96	
TE4			.95	
TE5			.96	
TE6			.95	
Factor 4: STEM, α = .98, variance explained = 25.78%				
STEM1				.94
STEM2				.96
STEM3				.95
STEM4				.91
STEM5				.91
STEM6				.94
STEM7				.93

Note: Overall Cronbach's α = .94. Total variance explained = 86.84%.

b) The Degree of Attitudes Towards Science, Technology, Engineering and Mathematics

Table 3 presents the degree of attitudes towards Science, Technology, Engineering and Mathematics among students. The dimension of Mathematics came in the first rank with a mean of (4.12) and standard deviation of (0.66) followed by Science with a mean of (3.99) and standard deviation of (0.61). Both of these two dimensions performed greater than the grand mean (3.88). Meanwhile, the technology and engineering appeared in the last rank with a means of (3.58) and standard deviations of (0.67). This result indicated that Mathematics became the dominant preference among student and following by Science compared to Technology and Engineering or STEM itself. This result represents the proportion of mathematics in junior high school curriculum greater than others.

Table 3. *Summary of the degree of attitude towards STEM*

Dimension	M	SD	Rank
Science (S)	3.99	0.61	2*
Mathematics (M)	4.12	0.66	1*
Technology and Engineering (TE)	3.59	0.67	4
STEM	3.83	0.62	3
Total	3.88	0.44	

* mean > grand mean

c) The Interrelationships among dimensions of Attitudes Towards Science, Technology, Engineering and Mathematics

The interrelationships among dimensions of STEM and STEM itself presented a varying results (see Table 4). The coefficient of correlation range from .220 to .409 that was useful for limited prediction based on the criteria of Creswell (2012). However, each dimension correlated each other at α =. 01. The result confirmed to us that most participants will find that they use a mix of these different attitudes, but some participants find they have strong tendencies towards one attitude. In other words, the students have a consistency in their attitudes regarding the component of STEM separately to the whole of STEM as an integral part of science, technology, engineering and/or mathematics. These findings address the goals of science, technology, engineering and mathematics education while providing meaningful knowledge, abilities and experiences for students.

Table 4. *The interrelationships among dimensions of STEM*

Dimension	1	2	3	4
1. Science (S)	--			
2. Mathematics (M)	.409**	--		
3. Technology and Engineering (TE)	.283**	.220**	--	
4. STEM	.250**	.344**	.300**	--

** p < .01

DISCUSSION

The study was designed to investigate the Indonesian junior high school students' attitudes towards STEM. Specifically, the study explored the degree of attitudes towards Science, Technology, Engineering and Mathematics, and examined the interrelationships among its dimensions. Supported by three science teachers, then the study was started by introducing and demonstrating teaching and learning process and integrating STEM education with topic "Hydrogen Fuel Cell". As stated as Stohlmann, Moore & Roehrig (2012), a support, teaching, efficacy and materials of considerations for teaching integrated STEM education was developed through a year-long partnership with a middle school. The STEM model is a good starting point for teachers as they implement and improve integrated STEM education. In the following step, a survey study was conducted to explore students' attitudes towards STEM.

In general, the findings indicated that the instrument (AT-STEM) used in this study had satisfactory validity and reliability. The instrument performed well in terms of the variance was explained (86.84%). In addition, the overall of Cronbach's alpha coefficient was .94 also indicated the high reliability scale. Therefore, the instrument can be used for further study, especially for the upper elementary school and junior high school which adopting STEM approach. For each finding based on the aims of the study will be discussed at the following part.

Turning to the first aim, the dimension of Mathematics came in the first rank and followed by Science as a component of STEM implied that Mathematics is a basic knowledge of bringing foundation to the other discipline. At the junior high school level (grade 7-9), instruction in science and technology are usually the responsibility of separate teachers. These findings also in-lined with Özgün-Koca & Şen (2011) who studied Turkish secondary school students' attitudes towards mathematics and science and found that students had generally positive attitudes towards mathematics and science courses. Mathematics was the most dominantly and favoured subject in Turkey (Özgün-Koca & Şen, 2011) as well as Indonesia (Frensidy, 2014). However, technology and engineering were leaving behind and need full supporting from science and mathematics. The science and technology standard of the NSES [National Research Council (NRC), 1996] represents content that goes well beyond typical science (Yager, 2004).

Regarding the second finding, there were significant interrelationships among the four dimensions of AT-STEM: Science (S), Technology-Engineering (TE), Mathematics (M) and STEM. In junior high school, the maths and science teacher is frequently part of a "team" of grade-level teachers who coordinate and ideally integrate instruction among the traditional academic areas. Mathematics and Science are more dominant on the curriculum content. Information and Technology (IT) teachers, on the other hand, teach one of the "specials". In many cases, students attend these specials while their academic teachers meet and plan as a team, for example, in terms of engineering, the science-physics teacher will cover the information about machine, product, engineering, electricity, electronics, and others. Thus, integration is more difficult at this level. So that is why this situation in-lined with Foster (2005) and the result of interrelationships among dimensions of STEM above which performed limited prediction each other even though there was significantly correlated in statistics. Figure 3 illustrates the interrelationships among science, mathematics, technology and/or engineering in junior high school in Indonesia based on the current situation and Table 4 above.

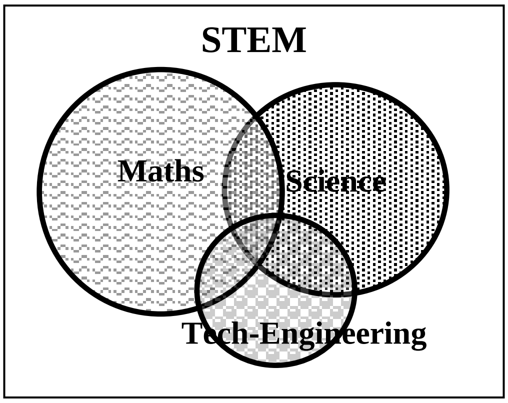

Figure 3. *The interrelationships among mathematics, science, technology and/or engineering in junior high school*

CONCLUSION and IMPLICATIONS

The result confirmed us that the instrument used in this study had satisfactory validity and reliability. The construct validities the AT-STEM were varying from .60 and .96 and explained 86.84% of the variance. Overall, the Cronbach's alpha coefficient of the instrument was .94. The dimension of Mathematics came in the first rank and followed by Science as a component of STEM. However, these instruments were developed to measure attitudes towards one of the STEM fields; thus, they follow the assumption that students learn STEM subjects only through traditionally, separated STEM education. Students' attitudes towards STEM are an important factor influencing student motivation to learn STEM subjects and pursue a STEM career (Maltese & Tai, 2011). The results also showed the significant interrelationships among dimensions of attitudes towards STEM. Surprisingly, STEM education in Indonesia still becomes a new issue in the current year. Therefore, the implications delineated contribute to the improvement of science curriculum in Indonesia and students' career.

In fact, STEM is everywhere. Our homes, our nourishment, our health, our safety, our relationships with family and friends and neighbourhoods, our jobs, our leisure are all profoundly shaped by technological innovation and the discoveries of science (Office of the Chief Scientist, 2013). STEM has and will continue to provide for everyone – to make available the new knowledge and technologies that are needed to address challenges, and to underpin new goods and services. For future study, it is important to take place the STEM education programs and to consider the 21st century skills as a foundation for STEM careers. Schools are integral to augmenting, diversifying, and equalising the STEM workforce because schools can inspire and reinforce students' interest in STEM in addition to academically prepare them to be able to follow a STEM career (Bottia et al., 2013). Therefore, the subject areas that involve mathematics, science, engineering and/or technology, and lists of jobs connected to each subject area (such as physicist, chemist, astronomer, biological scientist, mathematician, lab technician, analyst, veterinarian, etc.) need to be explored. This study also motivates K-12 schools, community colleges, and universities implement new STEM and 21st century skills programs, which is the fact that students in Indonesia have been performing below those from other countries.

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APPENDIX-1

Attitudes Towards STEM (AT-STEM) Questionnaire

Dear students,
Thanks a lot for completing this questionnaire. It is to understand your response to attitudes towards STEM. Your fill-in information will be used only for research and kept absolutely confidential. Please tick a choice according to your own perception. Thanks for your help. If you are interested in the result of my research, please give us a call.

Directions:

1. *There are five choices after the statement: Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A) and Strongly Agree (SA).*
2. *Please tick (√) the choice in the box according to your opinion.*

Thanks a lot.

Code	Items	Option				
		SD	**D**	**N**	**A**	**SA**
		1	2	3	4	5
S	**Science**					
S1	I know I can do well in science.					
S2	I expect to use science when I get out of school.					
S3	Knowing science will help me earn a living.					
S4	Science will be important to me in my life's work.					
S5	I will need science for my future work.					
S6	I would consider a career in science.					
S7	I can handle most subjects well, but I cannot do a good job with science.					
M	**Mathematics**					
M1	I enjoy learning mathematics.					
M2	I am good at math.					
M3	I am the type of student to do well in math.					
M4	I am sure I could do advanced work in math.					
M5	I can get good grades in math.					
M6	I would consider choosing a career that uses math.					
M7	I can handle most subjects well, but I cannot do a good job with math.					
TE	**Technology and Engineering**					
TE1	I enjoy learning to use technology.					
TE2	If I learn engineering, then I can improve things that people use every day.					
TE3	I am curious about how electronics work.					

TE4	I am interested in what makes machines work					
TE5	I like to imagine creating new products.					
TE6	I believe I can be successful in a career in engineering.					
STEM	**Science, Technology, Engineering and Math**					
STEM1	I would like to use creativity and innovation in my future work.					
STEM2	To learn engineering, I have to be good at science and mathematics.					
STEM3	Knowing how to use math and science together will allow me to invent useful things.					
STEM4	Science, technology, engineering and mathematics make our lives better.					
STEM5	Science, technology, engineering and mathematics are very important in life.					
STEM6	Science, technology, engineering and mathematics are good for the future of our country.					
STEM7	I would like to have a job that involves science, mathematics, engineering or technology.					

Part II: Personal Information

1. School name : ____.
2. Grade :

   ☐ (1) VII (7)

   ☐ (2) VIII (8)

   ☐ (3) IX (9)
3. Gender :

   ☐ (1) Male

   ☐ (2) Female
4. In the future, would you like to participate in this study? Please give me your e-mail if you attend all future researching activities. Thank you for your help.

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