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RETOOLING SCIENCE TEACHING ON STABILITY TOPIC FOR STEM EDUCATION: MALAYSIAN CASE STUDY

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Abstract

By 2020, Malaysia needs to develop its workforce capacity in order to obtain the 500,000 STEM human capital requirement for the New Key Economic Areas (NKEAs). Therefore, an effort of retooling teaching and learning of science teachers is a part of the planning in catalyst STEM human capital. Science teachers require refreshment in teaching and learning approach of pedagogy to enhance the student understanding in the subject matter and stability topic is chose as the initial idea to attract the student interest in STEM activities. This study aims to introduce a teaching aid Arts and Stability Card (A&S Card) to help teachers to diversify the teaching concept of stability science through A&S Card. 300 science teachers across the 10 districts from Perak state, provided their perceptions upon the modules via questionnaire in two parts: a pedagogical approach to teaching and learning, and training suitability. The reliability test of Chronbach's Alpha to the pedagogical approach to teaching and learning scored 0.868 while training suitability obtained 0.874, which fall under the very good category of reliability results. The mean result score of 4.29 and 4.17 to the pedagogical approach to teaching and learning, and training suitability, where the results indicate A&S Card module and training were successfully conducted. Besides, this module also contains the value of creativity and innovation to build a fun learning in a science subject and the concept can be replicated for other science subject.

Keywords: Arts and stability card, Soft skill, STEM education, Teaching aid.

1. Introduction

"Let's also remember that after parents, the biggest impact on a child's success comes from the man or woman at the front of the classroom. In South Korea, teachers are known as 'nation builders'. Here in America, it is time we treated the people who educate our children with the same level of respect. We want to reward good teachers and stop making excuses for bad ones. And over the next 10 years, with so many baby boomers retiring from our classrooms, we want to prepare 100,000 teachers in the fields of science and technology and engineering and math." - White House [1]

The quotation above states the beginning for STEM education. The movement does not only influence the United States of America, but it also encourages many countries to recognize its importance for the sake of their development, including Malaysia. This country targets to develop its workforce capacity of 500,000 STEM human capital requirement based on a 6% of the country's economic growth and the emergence of Entry Point Projects under the New Key Economic Areas (NKEAs) [2]. Those human capitals are expected to be the main driver of the nation's economic growth through intensive production of technological inventions and innovation.

In order to achieve the goals, science education plays an important role in developing creativity, critical thinking, and innovation to the future generation. The aim of the nation is to have a ratio of 60:40 of students taking Science compare to Art [3, 4]. Unfortunately, according to Balakrishnan et al. [5], the current ratio of the subjects is still 20:80. Moreover, the number of students who take the Malaysian Certificate of Education Examination in Science were only 90,000 in 2016, far less than the required annual number of 270,000 [6]. This statement above is supported by previous researches concerning students' motivation in science, focusing on their interest, attitudes, engagement to science learning, enrolment in science, and self-confidence [7-12]. Based on a study by Esra and Serhat [13], STEM education program for science teachers is important to enhance the science teaching competencies in planning, implementation and evaluation. All of these studies come into conclusion that the students' intention towards science declining after learning this subject, especially in secondary school. Therefore, an initiative needs to be taken to minimize the gap to the target and gain the number of students in the science class before the due of the vision.

2. Background of Study

2.1. Definition of STEM

STEM stands for Science, Technology, Engineering, and Mathematics. STEM education can be defined as a lifelong education that includes the integrated learning of STEM-based on informal curriculum through co-academic activities and co-curriculum and informally through indirect learning for every level age of group, starting from the early childhood, primary education, lower secondary education, secondary education, tertiary education, and industrial level or community.

2.2. Future needs of STEM

In order to obtain the vision of the country, Malaysian students must be engaged with STEM education as early as possible. The government can do this by providing a supportive education system prioritizing STEM education to harvest the targeted

number and quality of future human resources in Science and Technology (S&T). Figure 1 shows the future needs of STEM to achieve the target of the nation.

The scheme divides the needs into four stages, develop, harness, intensify, and transform the nation. The development of STEM comes through Education, by attracting the interest of pre and primary school students to choose STEM-related courses in upper secondary and tertiary education. It is hoped that the supply of secondary school students in the science stream should be high enough to reach the target of 60 Research and Scientist Engineer (RSE) per workforce by 2020. Harnessing many quality S&T human resources can be obtained through the planning of students' science in tertiary education. This stage provides enough capacity and a world-standard teaching and R&D platform in S&T. The exposure of job markets in tertiary education and after graduating can intensify students' S&T career paths. The jobs are ranged from private or government sectors and entrepreneurship. It is hoped that the higher the number of S&T capitals, the higher the chances to transform the nation towards better economic growth.

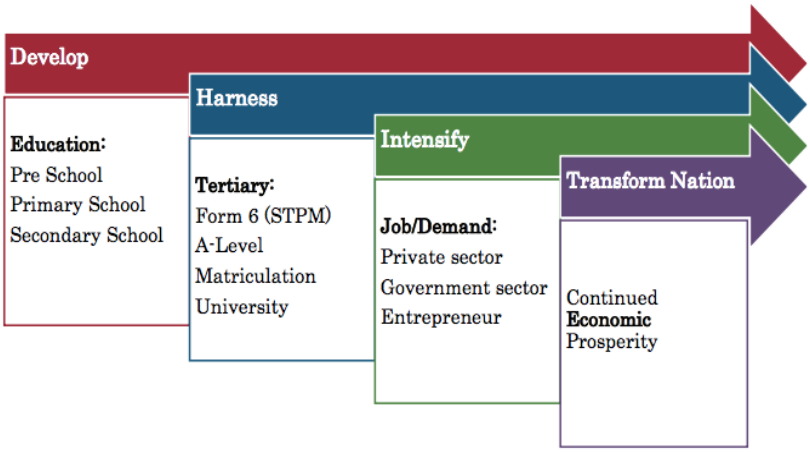

Fig. 1. STEM future needs.

2.3. Importance of STEM

STEM brings an urgency of driving the development of society and economy in Malaysia and a review study of STEM (1999-2013) shows the vital of STEM education in school [14]. In other words, S&T forms a backbone of emerging invention and innovation capacity with the constructive effects as stated in Fig. 2.

The Ministry of Science, Technology, and Innovation [15], in Science and Technology Human Capital Roadmap: Towards 2020, illustrates the implementation of enhancing STEM education and the action plans to target 500,000 S&T human resources by 2020 (Fig. 3). However, the milestone will not be achieved without any attempt to minimize the large gap from 2012 to 2020 to increase the number of S&T capitals to fulfil the workforce demands.

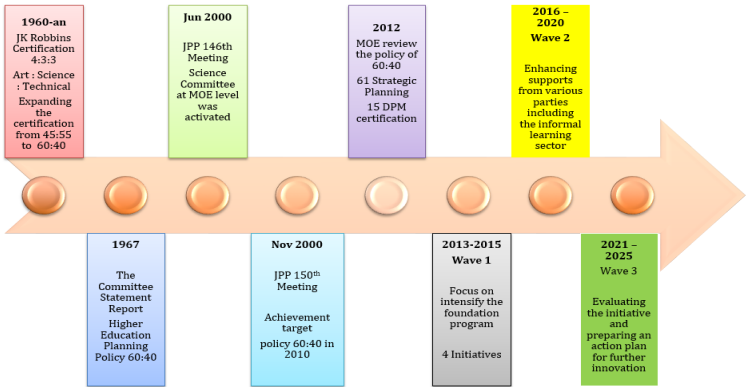

Fig. 2. Milestone of STEM education in Malaysia [16].

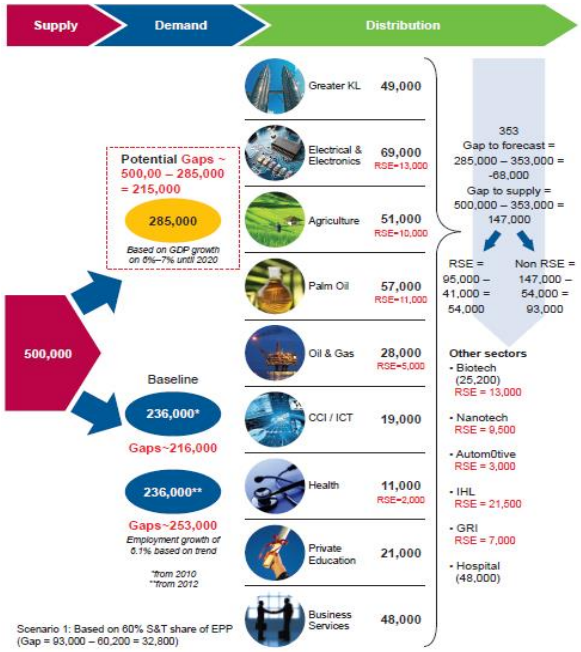

Fig. 3. S&T job market roadmap based on 60:40 job share [4].

2.4. Curriculum specification related to STEM education (HOTS)

The school-based assessment system introduced to assess students holistically and lessen the excessive focus on examination. It was rolled out in primary schools year one students in 2011 and for form one students in secondary schools in 2012. The students continuously assessed and graded from Band 1 (the ability to recall information) to Band 6 (the ability to have higher order thinking skills and knowledge).

The Malaysia Education Blueprint 2013 - 2025 probe the school-based assessment to international tests of the Trends in Mathematics and Science Survey (TIMSS) [17]. The study shows that the up to 38% of Malaysian students in TIMSS 2011 did not meet the minimum standards for Mathematics and Science. They are

generally struggled to apply this knowledge although they understood basic Mathematics and Science concepts. Only 2% of Malaysian students achieved 'advanced levels' in the TIMSS 2011.

The HOTS (Higher Order Thinking Skills) questions are making inroads to Malaysians, e.g., Sijil Pelajaran Malaysia (SPM), Pentaksiran Tingkatan Tiga (PT3) and Ujian Pencapaian Sekolah Rendah (UPSR). HOTS is inserted to make students able to apply what students have learnt in new and different settings. It enhances their analysing, rationalizing, reasoning, communicating, and decision making abilities for the sake of their living.

In relation to STEM, HOTS should be properly conducted in Science and Mathematics lessons. The lessons should incorporate the elements of observation, systematic data collection, tabulation and graphical, interpretation, comparison, inferences, analysis, projection, induction, deduction, and synthesis to prepare students' to face the questions. Then, HOTS encapsulates critical and creative thinking. This idea can be developed by creating modules that could combine both HOTS and curriculum requirements in Science education.

3. Statement of the Problems

From the series of a workshop conducted under the National STEM movement, teachers found lacking in creativity and innovation in teaching science. Although they have started to use a student-centered teaching approach, there is still lack of hands-on experiment and exercises. However, the engagement of students in learning science is important to build their interest and appreciation for science concepts. In the other hand, the government, through Malaysian Examination Syndicate (Lembaga Pemeriksaan Malaysia) had aimed to reintroduce centralized practical exams in SPM for Physics, Chemistry, Biology, and Additional Science in 2016. Somehow, this effort still suspended to give teachers and students chances and times to adapt to its implementation, while also equipping and standardizing the Science labs in schools nationwide.

As an effort of preparing the students and teachers to the exams, it is important for them to have educational method engaging with a hands-on element in science teaching and learning. Therefore, a module that integrates both theoretical and practical elements needed for learning science in Malaysia. From the explanation above, this research aims to retool science teacher, focusing on introducing innovative teaching kit to attract students and teachers' attention to STEM. In this case, the kit will be given based on the material of the integrated science module form 2 chapter 9 under the topic of stability science. This topic was chosen as an exercise for teachers with the hope that it will initiate the creation of similar kit for other topic.

4. Purpose of the Study

This study aims to introduce a teaching aid to help students to understand the concept of Stability Science. The aids itself is made to develop students' soft skill and hard skills. According to Mustapha et al. [18], soft skills technique helps the students to encourage their critical thinking and problem-solving. On the other hand, hard skill technique helps the students to master book materials [19]. The development of A&S Card produces an educational kit to help students develop their soft skills and a learning module to help them improve their hard skills.

The A&S Card educational kit is made because in science, students need to understand both the concept and its application in real life. The concept of the cards is based on the concept of building's 'critical load'. It is the weight at which, building or structure fails or collapse. The most efficient structure of the building is strong and lightweight, which is a difficult combination to achieve.

Meanwhile, the module of the A&S Card is formulated based on the STEM module, which is introduced by the Ministry of Education for school [20, 21]. The materials of the module are in accordance with the form 2, chapter 9 regarding Stability Science [22]. It is covered under the topic of understanding the center of gravity affects stability. The material includes Project-based Inquiry Learning approach. Furthermore, the content of the module contains four learning phases of the inquiry phase, exploration phase, design and experiment phase, and reflection phase.

5.Methodology

The study was carried out at Perak state of Malaysia. It was conducted with quantitative approach. The data were collected as the description of A&S Card design and the observation to teachers' responses to the use of the medium in the class.

The evaluation for the medium came from content domain experts and pilot study's reliability test. A&S Card was initially validated by three experts in the education field. Then, for the reliability of the respective medium, a pilot study was run to 30 chosen experts science teachers with the help of Perak State Education Department (JPN Perak). They were given a set of questionnaires to evaluate the reliability of A&S Card. The instrument for the set has two sections, A (respondent demography) and B (module questionnaire). Section B has two parts focusing on the pedagogical approach to teaching, learning, and training suitability. Each part has 8 items, which are measured on a 5-point Likert scale (1: Most Disagree, 2: Disagree, 3: Uncertain, 4: Agree, 5: Most Agree). A reliability index is a degree to which, a test consistently measures whatever it claims to be measuring [23].

The standard of reliability coefficient of 0.70 is usually associated with the instrument's reliability [24] and was adopted as the benchmark for the instrument in this study. The data were analysed using the SPSS software package based on Cronbach's Alpha coefficient. The test obtained the reliabilities at 0.874, which is considered 'very good'. Later, this instrument was used to a bigger population of 300 teachers as the samples of the study as shown in Table 1. The age of secondary science teachers was involved in the study is ranged from 30-50 years old.

Table 1. Sampling data of science secondary teachers in Perak.

District	Male	Female	Total
Kerian	5	15	20
Perak Tengah	6	13	19
Kinta Selatan	9	11	20
Kinta Utara	13	33	13
Kuala Kangsar	8	22	30
Larut Matang & Selama	6	34	40
Hulu Perak	5	15	20
Hilir Perak	7	23	30
Manjung	5	24	29
Batang Padang	11	23	34
Muallim	3	9	12
Total	**78**	**222**	**300**

6. Results and Discussion

The analysis of the results focuses on two materials, namely the description of the A&S Card as the developed medium for learning science and the analyses from the tabulated questionnaires' responses.

6.1. Development of arts and stability card

The developed teaching kit in this study named Arts and Stability Card or A&S Card. This medium consists of 15 pieces of interactive and colourful card. A&S Card introduces the students to the concept of critical load. It is the maximum weight at which, a building or structure collapse or fails. To use it, the students are asked to build a double or single storey structure using the card to hold a 500 ml full water bottle on the structure or design a base area to hold a textbook place onto it. They can simply observe and redesign the building if the structure they make is collapse or fails. Through this activity, the students are able to test a building's design and explore the factors of building's stability as presented in Fig. 4.

To support the learning process, there is also a module to guide students according to the STEM module. In this module, students are introduced to the concept of stability. They will initially be directed to achieve the objectives of the learning process before starting the experiment. The learning objectives are the inquiry phase in STEM module. Exploration phase is where students acquire to familiarise with the tools to be used in the experiment. Furthermore, students will explore through the experiment's instruction and organize themselves for the experiment. After that, students will design the building based on the instruction and modify it to perform a different test for the experiment.

(a) Single storey.

(b) Double storey.

(c) Small base area.

(d) Large base area.

Fig. 4. Form of arts and stability cards.

This is the design and experiments phase. Lastly, reflection phases are the outcome that students' gain for each experiment. It is recorded in the activity 1 (Centre of Gravity) as presented in Table 2 and Activity 2 (Effect of base area on stability as illustrated in Table 3. The students will discuss in their group for the outcome based on the objectives in the inquiry phase. Besides, there are six (6) reflection questions to evaluate their understanding of the topic.

As the implementation of retooling science teachers, this medium is presented as a training kit for the object of the study. The training was to 330 science teachers from 248 secondary schools in Perak. The documentation of the training can be seen in Figs. 5 and 6.

6.2. Teachers' perception of the use of arts and stability card

A set of questionnaires was given to 300 teachers regarding the teaching module of Arts and Stability Card. The responses of the questionnaires given by 300 science teachers were analysed to obtain their overall perception. Each item's analysis is presented in Tables 3 and 4.

6.2.1. Pedagogical approach

The result begins with the information of teachers' perception to the educational procedures of classroom activities assisted with A&S card. In details, Table 4 illustrates the tabulation of average teachers' responses to eight questionnaire items of the pedagogical approach for teaching and learning of A&S Card module.

Table 2. Activity 1: Centre of gravity.

Activity	Weights, ml	Stability of structure (Please tick) Pass	Fail
Double storey	500		
	1000		
	1500		
	2000		
	2500		
Single	(Use weights that make single storey structure collapse)		

Note: Constant variable: Mass of weight (water bottle)
Manipulated variable: Height of structure
Responding variable: Stability of structure
*Pass (/) or Fail (x)

Table 3. Activity 2: Effect of base area on stability.

Activity	Stability of structure (Please tick) Pass	Fail
Small base area		
Large base area		

Note: Constant variable: Mass of weight (books of 3 cm thick)
Manipulated variable: Size of base area
Responding variable: Stability of structure

* Pass (/) or Fail (x)

Fig. 5. The trainees build two storey building using A&S cards.

Fig. 6. The trainees build single storey building using A&S cards for multiple water bottles.

Table 4. Mean score for each of the eight items in the pedagogical approach for teaching and learning.

Number	Item	Mean score
1	Suitability of content	4.36
2	Suitable for the given topic	4.4
3	Reflective questions are of diverse cognitive skills	4.12
4	Reflective questions encourage creative thinking	4.19
5	Questions were based on the learning standard for KSSM	4.23
6	Problem solving skills	4.23
7	Test on conceptual understanding	4.32
8	Increase students' motivation	4.45
	Total	**4.29**

Table 4 shows an overall positive response with a mean score of more than 4 (4.29). The overall responses skewed to the right, showing that all respondents "agree" or "most agree" that the educational procedure for teaching and learning with A&S Card matches to the topic of stability science. Most of the teachers agreed that the use of the medium could increase students' learning motivation with a mean score of 4.45. It indicated that the arranged activities in the module could motivate the students to learn about stability science. Items 1 and 2 present an average score of 4.36 and 4.4, showing that the respondents came into agreement

that the content and topics of the handout are suitable to the subject of form 2. It is supported with Item 5 (Mean score = 4.12), which depicted similar result; that is to say, the questions prompted in the module is deemed having the required standard of the syllabus for students in school.

These results make the overall responses to overall conceptual understanding (Item 7) in the positive range at the point of 4.32. In conclusion, the module is proven reliable as the teaching kit developed to improve students' understanding upon the concept of stability. With the respect of the module's reflective questions, the respondents agreed that the questions feature diverse cognitive skills (Mean score = 4.12) and encourage students' creative thinking (Mean score = 4.19).

6.2.2. The suitability for training

Besides its suitability for classroom activities, the module was analysed for its suitability as a training object. The overall average scores for each questionnaire's item in terms of suitability for the training of A&S Card is presented in Table 5.

Table 5. Mean score for each of the eight items in the suitability for training.

Number	Item	Mean score
1	Brief instructions	4.29
2	Clear instructions	4.27
3	Clear illustrations	4.21
4	Precise illustrations	4.22
5	Suitable font size	4.11
6	Suitable font type	4.22
7	Correct use of language	4.25
8	Applicable duration time of activity	3.82
	Total	**4.17**

For the suitability for training, the analysis of A&S Card also skewed to the right. It suggests that most respondents "agree" or "most agree" that the module is suitable to become the training object for the topic of stability science. The module depicts almost all mean scores (7 and 8) in more than Likert scale 4 (4.17). The only item, which has a mean score slightly below 4 is Item 8 (Mean score=3.82). This lower score indicates that the trainees need to take more time to master the skill of balancing the cards in the training. In contrary, most of the teachers agreed that the module has brief instruction with the highest mean score of 4.29. Another aspect concerning the instruction of the module, Item 2, followed behind with 4.27. Next, the respondents deemed that the language in the module is proper enough for the training with a mean of 4.25. For the illustration, the teachers agreed that the module provides a precise and clear illustration with the average score of 4.22 and 4.21 respectively. In terms of the used fonts in the module, the teacher considered them as having suitable type and size. These aspects got the mean score of 4.22 and 4.11.

7. Conclusions

The main aims of A&S Card's development is to weaponized science teachers with a fresh and interactive medium for the teaching and learning of science. The characteristics of the medium will help teachers to optimize students' chances to get hands-on experiments and exercises in the classroom. As the teaching kit is designed with the criteria of user-friendly, cost-effective and laboratory free,

therefore, the classroom activity will be enlivened with a student-centered and exciting way to teach science to stability science, instead of spending more time to theoretical discussion. Later, this initiative will also help the government to promote the area of STEM learning by attracting the interest of students with effective and interesting teaching.

In order to gain support from teachers, analysing their perception of A&S Card module is important its development. For the pedagogical approach of the media, the teachers, as the respondents of this study, considered that this medium is most appropriate to motivate students' learning motivation. This statement supports the results of previous researches that motivation in science learning is crucial to building the learning interest of students to explore the subject further [25-27]. For the suitability of training, the only lack, which can be improved, is in terms of the duration of the activity. The need for longer duration is due to the less familiarity with some teachers in building structures using cards; thereby, they will take a longer time to do this. It is evident as some of them have the difficulty to balance the cards during the activity. Therefore, as timing is important in training and classroom activity, the direction of structuring and building the cards should be an important concern for the trainers and teachers. It is mainly to avoid overtime session or leaving some teachers and students incapable to understand the building and concept of card building's critical load.

In conclusion, A&S Card provides a chance for teachers and students to integrate theoretical and practical elements in science teaching as well as enhance students' interest to STEM. The material can be used to illustrate the concept of stability to students because it is easily accessed. This module may also help the teacher to teach science and generate ideas to innovate the medium or to develop other teaching aids to make teaching and learning of science more attractive in schools.

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