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PRO-STEM Module: The Development and Validation

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Abstract
This study was conducted to develop a PRO-STEM module for teaching the topic of "Biodiversity and Ecosystem" in Science for Form Two students. In this module, the concept of Science, Technology, Engineering, and Mathematics (STEM) is integrated using a project-based learning approach to promote the application of higher order thinking skills (HOTS) and 21st century skills among secondary school students. This module is developed based on the Sidek Module Development Model. A total of five experts in STEM and science education were appointed to validate the PRO-STEM module. The content validity index (CVI) obtained for PRO-STEM module was .976. Findings from the pilot study were analysed and the Cronbach's alpha for reliability obtained was .924. These findings show that PRO-STEM module has good validity and reliability and is capable of being used as a teaching and learning module to integrate STEM in science classrooms.
Keywords: Module, STEM, Project Based Learning, Biodiversity, Ecosystem.

Introduction
Science, Technology, Engineering and Mathematics (STEM) education has been given emphasis by the Ministry of Education (MOE) and the Ministry of Science, Technology and Innovation (MOSTI) in order to ensure that Malaysia's education is in line with the goals of the Science, Technology and Technology Policy National Innovation and Malaysia Education Blueprint 2013-2025 (Ministry of Education Malaysia, 2013; MOSTI, 2016). This is because STEM education has many advantages in transforming the teaching and learning (T&L) of science towards more creative and innovative strategies to meet the needs of today's Net Generation (Kamisah, Lee, & Vebrianto, 2013).

The STEM concept can be integrated into science T&L by project, problem, and inquiry based approaches (Ministry of Education, 2016). Recent studies suggested that STEM is best integrated with project-best learning (Khairani, 2017; Sahin, 2015) as it can provide real world learning experiences in science (Ayob et al., 2015; Kelley & Knowles, 2016; Laur, 2013) and allows students to work collaboratively to solve challenging questions (Krajcik & Czerniak, 2014). In addition, project-based learning is effective in increasing communication skills (Wan Nor Fadzilah et al.,

2016), creativity and collaboration skills (Ayob et al., 2015), critical thinking and problem solving skills (Bell, 2010) which will further develop higher order thinking skills (Slough & Milam, 2013). The skills, knowledge and understanding of STEM are crucial for the young generation to succeed in an increasingly science and technology driven society (Banks & Barlex, 2014).

However, Ramli and Talib (2017) found that science teachers' lack of efficacy in integrating STEM is still making them unconfident to integrate STEM in science classrooms (Nadelson et al., 2013). Thus, integration of STEM in classrooms is still at a moderate level (Nur Diyana, Haryati, Emeliana, Lilia Ellany, & Lilia, 2016; Rasul et al., 2015). Teacher's efficacy and preparedness to deliver STEM concepts are crucial as students depend on their teacher to acquire the accurate STEM contents (Nadelson et al., 2013).

Thus, it is important to provide teachers with guidelines or science teaching strategies to promote the implementation of STEM in classrooms (Nur Diyana et al., 2016). In addition, students' understanding about STEM should be inculcated not only at higher education level, but primary and secondary level as well. However, a well-developed teaching module for lower secondary school science teachers to implement STEM in classrooms is still unavailable. Thus, there is a need to develop a teaching module incorporating STEM and applying a project-based learning approach.

Literature Review
Science, technology, engineering and mathematics used to be taught separately as four discrete subjects in schools (Capraro & Slough, 2013). However, these subjects are interconnected in our everyday life (Banks & Barlex, 2014). Recently, science, technology, engineering and mathematics have been integrated into a single discipline known as STEM. This interdisciplinary approach may help students to apply the STEM concepts with real world lessons to provide better cognitive and skills development.

The recent urge by educators and policy makers on the advancement of STEM education is mainly due to the need to improve STEM skills among the younger generation (English, 2016) to meet the increasing demands for STEM professionals (Trna & Trnova, 2015). Thus, it is crucial to equip the students with skills and in-depth conceptual understandings on STEM so that they are prepared to face the challenges and be competitive globally (Kementerian Pendidikan Malaysia, 2016). Banks and Barlex (2014) explained the purpose of STEM concepts in education as shown in Table 1.

Table 1 The purpose of STEM concepts (adapted from Banks and Barlex, 2014)

Concept	Purpose
Science	A high-quality science education provides the foundation for understanding the world through the specific disciplines of biology, chemistry and physics.
Technology	Equips pupils to use information technology to create programs, systems and a range of media. It also ensures that pupils become digitally literate – able to use, and express themselves and develop their ideas through information and communication technology – at a level suitable for the future workplace and as active participants in a digital world.
Engineering	Using creativity and imagination, pupils design and make products that solve real and relevant problems with a variety of contexts, considering their own and others' needs, wants and values.
Mathematics	Mathematics is a creative and highly inter-connected discipline that has been developed over centuries, providing the solution to some of history's most intriguing problems. It is essential to everyday life, critical to science, technology and engineering, and necessary in most forms of employment.

STEM-focused teaching and learning can bring a meaningful and fun learning experience (Ayob et al., 2015) to students who can increase their interests and tendencies towards the STEM field (Edy Hafizan, Lilia, Mohamad Sattar, Kamisah, & Mohd Afendi, 2016). Hence, more students will choose STEM in their post-secondary education (Edy Hafizan et al., 2016; Peterman, Kermish-Allen, Knezek, Christensen, & Tyler-Wood, 2016).

STEM that integrates knowledge, skills and values can be implemented through inquiry approaches, project-based learning and problem-based learning in real-world contexts (Ministry of Education, 2017). The difference between problem-based learning and project-based learning is that problem-based learning (PBL) focuses on relating real world problems to student's prior knowledge and they need to discover new knowledge to solve the problem. Whilst in project-based learning (PjBL), students carry out extended activities to solve a challenging authentic task and demonstrate their abilities in researching and investigating new knowledge and acquire the skills regarding projects (Banks & Barlex, 2014). Hence, students who learn using STEM PjBL instruction show better collaboration and communication skills compared to lecture instruction (Han, Capraro, & Capraro, 2014).

Capraro and Slough, (2013) believed that PjBL provides the contextualised, authentic experiences necessary for students to scaffold learning and build meaningfully powerful science, technology, engineering, and mathematics (STEM) concepts. STEM PjBL approach requires the students to think critically and analytically which will further develop their higher order thinking skills (HOTS) (Capraro & Slough, 2013; Slough & Milam, 2013). In general, STEM PjBL allows students to demonstrate their skills which couldn't be shown from written exams solely (Banks & Barlex, 2014). Moreover, See, Rashid and Bakar (2015) emphasised that a student-centered T&L approach like PjBL should be taken into consideration as a teaching approach to encourage students to think creatively, critically and innovatively.

The STEM PjBL approach can be conducted in classrooms based on the 5E model (engagement, exploration, explanation, extension and evaluation) and engineering design process. Basically, the engineering design process has seven steps; identifying a problem, research, ideate, analyze idea, build, test and refine, communicate and reflect. In fact, the engineering design process fits well with the 5E learning cycle model. Table 2 shows the alignment of the seven step engineering design process and 5E model adapted from Capraro, Capraro and Morgan (2013).

Table 2 Alignment of 5E Model with Engineering Design Process (adapted from Capraro, Capraro and Morgan (2013).

5E Steps	Design process steps
Engagement	Identify problem
Exploration	Research, Ideate, Analyse Ideas
Explanation	Research, Ideate, Analyse Ideas
Extension	Build, Communicate
Evaluation	Test and Refine, Reflect

Thus, to develop an instruction based on STEM PjBL, the 5E model was adapted and aligned with the engineering design process.

Research Objectives
The objectives of this study are to:
1. Develop a project-based learning module that integrates the STEM concept.
2. Determine the validity and reliability of the PRO-STEM module.

Methods
Development of PRO-STEM module
Module development is a developmental study that involves several phases and steps (Yusop, Sumari, & Mohamed, 2015) and engages with certain models of module development that suit the module's objective. In this study, Sidek Module Development Model (Sidek & Jamaludin, 2005) was adapted to develop PRO-STEM module. The module development process involves two main stages, namely the preparation of draft module and evaluation of the module.
   First Stage: Preparation of draft module
   The preparation of draft module began with determining the learning theory, needs analysis, setting the goals, selecting materials and compilation of draft module. At this stage, the module is still known as a draft because its validity and reliability has not yet been proven (Sidek & Jamaludin, 2005).
      a) Determining the learning theories
         Theory of constructivism is underlying the STEM PjBL approach. In the theory of constructivism, the emphasis is more on the student than a teacher. This is because students who interact with material and situation will gain an understanding about it. Thus, students build the concept on their own and create solutions to the problems. Teachers are responsible to accept the students' initiative and to encourage them to put more effort into learning (Nur Diyana et al., 2016).

b) Needs analysis

In this study, the researcher carried out a survey to seek experienced science teacher consensus on the need of STEM integrated teaching module. The criteria used by the researcher to select the expert were based on:

i. The teachers had at least five years' experience in teaching science.

ii. The teachers were in-service teacher in secondary schools.

Five point fuzzy scale questionnaires were distributed by e-mail to volunteer expert science teachers between July to August 2017. The result was analysed using Fuzzy Delphi method to obtain the percentage of expert teachers' consensus. The involvement of 20 respondents in this study is considered sufficient as Jones and Twiss (1978) claimed that the number of experts as respondents for Delphi method is between 10-50 respondents. Table 3 below shows the findings from needs analysis that have been analysed using Fuzzy Delphi method.

Table 3 Findings in needs analysis using Fuzzy Delphi method

Item	Expert agreement (no of item d ≤0.2)	Percentage of expert agreement	Interpretation
The need to occupy students with STEM knowledge	18	90%	Accepted
The need to occupy students with STEM skills	19	95%	Accepted
STEM can be integrated using PjBL approach	18	90%	Accepted
Teachers need to be provided with reference materials for integrating STEM in classroom	20	100%	Accepted
More STEM integrated teaching module should be developed	20	100%	Accepted
Percentage of expert consensus on the need of STEM integrated module is 95.0%			

According to Mohd Ridhuan, Saedah, Zaharah, Nurulrabihah, & Ahmad Ariffin (2017), the percentage of expert consensus must be more than 75%. Thus, based on the findings in Table 3, 95.0% of expert science teacher consensus has been achieved for the need to develop integrated STEM teaching module.

Table 4 Expert percentage agreement on the suitable topic for integrated STEM module

Topic	Expert agreement	Percentage of expert agreement
Biodiversity	9	45%
Ecosystem	7	35%
Nutrition	3	15%
Human Health	1	5%

Table 4 shows that Biodiversity (45%) and Ecosystem (35%) were the two top science topics chosen as suitable topics that can be integrated with STEM. This finding is also supported by a study conducted by Koay and Maria (2016) that examines 14 years old students' misconceptions on science in Trends in International Mathematics and Science Study's (TIMSS) items. According to Koay and Maria Salih (2016), of the three items (item 17, item 21a and item 21b) in the Ecosystem topic, the percentage of students' incorrect responses were 30.3% (item 17), 51.0% (item 21a) and 37.2% (item 21b). Most of them stated that they did not understand the concept of science in the question; 37.4% (item 17), 33.3% (item 21). Thus, by developing the STEM integrated teaching module, the researchers hope to help students to understand the scientific concept in the topic of Ecosystem and Biodiversity.

c) Setting the goals- The goals for this module are to inculcate higher order thinking skills and 21st century skills among secondary school students.

d) Selection of materials
STEM PjBL approach was perceived as a challenging approach by the teachers as it took a longer time to implement (Pryor, Pryor, & Kang, 2016) with limited time allocated for science T&L (Siew, Amir, & Chong, 2015). This approach also requires good selection materials to engage student in project based activities. Thus, in this PRO-STEM module, only recyclable materials are used so that teachers and students may not encounter problems in preparing materials for the selected project.

e) Compilation of module's draft
Once all materials needed and the suitable projects have been identified, the arrangement of the projects into a module is done. All the projects are arranged according to Standard Curriculum and Assessment for secondary schools provided by the Ministry of Education.

Second Stage: Evaluation of module
Second stage of module development according to Sidek and Jamaludin (2005) involved the validation of module by experts and study on reliability.

i) Content validity
The content validity of PRO-STEM module was evaluated by five experts in STEM and Science education. Content validity is then calculated using CVI (content validity index) as suggested by Polit, Beck and Owen (2007) and Zamanzadeh et al., (2015). The CVI is an index of inter-rater

agreement that is widely used as an approach to calculate the proportion of agreement. CVI can be computed by calculating the average of experts' agreement on item (I-CVI) by denoting relevant item as 1 and irrelevant as 0. Polit, Beck, & Owen, (2007) recommended the value of I-CVI must be at least .78 or above to indicate good content validity when there are three or more experts involved. S-CVI is the overall content validity for scale and researcher often use .80 as the lower limit of acceptability for S-CVI.

ii) Reliability
A pilot test was conducted involving 30 secondary school students to test the reliability of the module. Plus, the pilot test is also a crucial step to determine the usability of the module within the time allocated and to identify the problems that may arise during module implementation.

Findings and Discussion
Development of PRO-STEM Module
PRO-STEM Module has been developed based on the Constructivist Learning Theory and Sidek Module Development Model. In the development stage for the module, needs analysis was carried out using a survey method. 20 expert science teachers were involved in the needs analysis study and the finding shows that there is a need to develop an integrated STEM teaching module. The finding also shows that the project based learning is the most suitable teaching approach to integrate STEM and two science topics were chosen to be included in the module; Biodiversity and Ecosystem.

Content Validity of PRO-STEM module
According to Sidek and Jamaludin (2005), the content validity of a module must meet the following criteria:
   i.   The module needs to meet the target population
   ii.   Module implementation method is satisfactory
   iii.   The time allocated to implement the module is sufficient
   iv.   Able to improve student achievement
   v.   Able to change student toward positive attitude

Table 5 shows the I-CVI and S-CVI/average to measure experts' consensus on PRO-STEM module.

Table 5 I-CVI and SCI-Average to evaluate expert consensus on PRO-STEM module

Criteria	Item	Relevant	Not relevant	I-CVIs	Interpretation
1. Module presentation	1. Use of language	5	0	1.00	Excellent
	2. Use of text	5	0	1.00	Excellent
	3. Graphic quality	5	0	1.00	Excellent
	4. T&L activity arrangement	5	0	1.00	Excellent
	5. User friendly module	5	0	1.00	Excellent
2. Integrated STEM approach	6. Real world issues	4	1	.80	Excellent
	7. Integrating 5E model	4	1	.80	Excellent
	8. Encourage learning by doing	5	0	1.00	Excellent
	9. Application STEM research process	5	0	1.00	Excellent
3. Time allocation	10. Time allocation to complete STEM projects is rationale	5	0	1.00	Excellent
4. Suitability to target population	11. Module is suitable for students age 13-14 years old	5	0	1.00	Excellent
5. Ability to develop 21st century skills	12. Digital age literacy	5	0	1.00	Excellent
	13. Inventive thinking	5	0	1.00	Excellent
	14. Communication skills	5	0	1.00	Excellent
	15. Spiritual values	5	0	1.00	Excellent
	16. High productivity	5	0	1.00	Excellent

6.	Ability to inculcate higher order thinking skills (HOTS)	17.	The module is able to inculcate HOTS	5	0	1.00	Excellent
			S-CVI/ Ave= 0.976				

All five experts appointed to validate the PRO-STEM module gave consensus that PRO-STEM module has good content validity. This is shown by all items in the questionnaire having an I-CVI above .80 while the S-CVI obtained is .976 which exceeded the minimum I-CVI (.78) and S-CVI (.80) value which was recommended by Polit, Beck, and Owen, (2007).

The reliability of the module was determined using Cronbach's alpha coefficient. In this study, Cronbach's alpha coefficient obtained was .924 and it is considered very high as Sidek and Jamaludin (2005) suggested .85 as the coefficient of reliability that can be applied in research.

Conclusion

To conclude, the experts' consensus shows the PRO-STEM module has good validity. Thus, this module may help the teachers to integrate STEM instruction among secondary school students. However, the module developed only covered two science topics; Biodiversity and Ecosystem. Further research to develop STEM integrated teaching module covering more science topics is encouraged.

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