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The Effectiveness of Hands-On Modules in Learning Science

A Case Study in Malaysia

BALAMURALITHARA BALAKRISHNAN, MOHAMED NOR AZHARI AZMAN, AISYAH MOHAMAD SHARIF, MOHD IKHWAN HADI YAACOB, HANIZA HANIM MOHD ZAIN, AND PARMIN

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The Effectiveness of Hands-On Modules in Learning Science: A Case Study in Malaysia

Balamuralithara Balakrishnan,[1] Sultan Idris Education University, Malaysia
Mohamed Nor Azhari Azman, Sultan Idris Education University, Malaysia
Aisyah Mohamad Sharif, Sultan Idris Education University, Malaysia
Mohd Ikhwan Hadi Yaacob, Sultan Idris Education University, Malaysia
Haniza Hanim Mohd Zain, Sultan Idris Education University, Malaysia
Parmin, Universitas Negeri Semarang, Indonesia

Abstract: The main aim of this study is to examine the effectiveness of two novel learning modules, namely the Arts & Stability Card and Magnobolt modules, on the understanding of relevant concepts of stability and electromagnetism, respectively, among Malaysian secondary school students. The modules were developed based on the Malaysian Secondary School curriculum for science subjects that promote hands-on activities in the classrooms. A quasi-experimental method was used that involved two control and two experimental groups. Students in experimental groups used the novel learning modules, whereas those in the control group used the conventional learning materials. For the evaluation of the Arts & Stability Cards module, forty-eight and fifty students were assigned to the control and experimental groups, respectively. For the evaluation of the Magnobolt module, seventy-nine and seventy-eight students were assigned to the control and experimental groups, respectively. A series of t-tests were performed to determine if there were any significant differences between students' learning performances before and after the learning treatments. The analysis revealed that those in the experimental groups outperformed those in the control groups, strongly suggesting that hands-on activities afforded by such learning modules would help students to learn complex, abstract scientific concepts more efficaciously. Premised on these findings, it is therefore vital for teachers to improve the current pedagogy by integrating hands-on activities into the teaching and learning process with the use of such learning modules.

Keywords: Hands-On Activities, Learning Modules, Pedagogy, Science Education

Introduction

The efforts in enhancing science, technology, engineering, and mathematics (STEM) education in many nations continue to grow as the demand for STEM skills to meet economic challenges has increasingly become more intense (English 2016). As such, it is hardly surprising to note that educators, researchers, and policymakers all over the world have become preoccupied with such effort to advance the competencies in the STEM domain. Admittedly, the nature and the scope of the development of proficiencies in STEM education vary among nations (English 2016).

For example, in Malaysia, many efforts have been carried out to promote STEM education among students, but such efforts have made a little impact thus far. More alarmingly, there seems to be a trend in which the number of students choosing STEM-related programs in institutions of higher learning has dropped quite dramatically, thus raising concerns among practitioners in view of the pressing need for skilled workforce (Jayarajah et al. 2014). A downward trend therefore demands new strategies that need to be implemented urgently in Malaysian schools to improve the current model of the teaching and learning process of STEM subjects or courses.

[1] Corresponding Author: Balamuralithara Balakrishnan, Level 3, E-Learning Building, Sultan Abdul Jalil (KSAJ) Campus, Faculty of Art, Computing and Creative Industry, Sultan Idris Education University, Tanjung Malim, Perak, 35900, Malaysia. email: balab@fskik.upsi.edu.my

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In this regard, the feedback for the Malaysia Education Blueprint 2013–2025 has highlighted several pertinent points, one of which is that few teachers have grasped the magnitude of the change that is impacting the educational landscape (PADU 2018). In addition, Malaysia Education Blueprint emphasizes the needs to compare the local examination standard to those of international tests, such as the Trends in Mathematics and Science Survey (TIMSS) (PADU 2018).

For instance, in 2010, the TIMSS was carried out involving a sample of Form-Two students (equivalent to Grade 8 students), who later sat for the Lower Secondary Assessment Examination in 2011. This survey found that approximately 38 percent of such Malaysian students failed to meet the minimum standard for mathematics and science (Ismail et al. 2017). Specifically, even though these students knew the basic mathematical and scientific concepts, the struggled to apply such conceptual knowledge. More revealingly, only 2 percent of the students achieved "advanced levels" in the TIMSS 2011, with 32 percent of the same group of students receiving an A grade in the PMR 2011(Lower Secondary Examination) examination (Ismail et al. 2017).

Furthermore, based on a series of workshops conducted under the National STEM Movement, teachers were found to be lacking in creativity and innovation in conducting their classes, which could be detrimental to student learning, as students' engagement in learning science through novel approaches, such as hands-on activities, to help create a deep interest in STEM among students (Kelley and Knowles 2016).

Although most science teachers have begun to use the student-centered teaching approach, there seems to be a lack of emphasis on hands-on experiments and exercises. Thus, students lack of learning opportunities to appreciate and apply relevant scientific concepts that can help develop their interest and practical skills in science subjects (Korsun 2017).

In 2001, the centralized practical tests for science subjects in the Malaysian Certificate of Education (SPM) examination (equivalent to GCE O-Level) were replaced by written tests and continuous school-based practical science assessments (Balakrishnan and Azman 2017). However, the scores of the school-based practical science assessments are not included in the Malaysian Certificate of Education (SPM) score. As a result, teachers tend to rely on the "chalk-and-talk" approach to explain relevant theories rather than encouraging their students to conduct science experiments in schools. Clearly, such a mundane approach hampers the efforts in promoting hands-on activities in learning science.

To improve the mastery and interest in science subjects among students, it is therefore important for Malaysian teachers to use a novel pedagogical approach that embeds a hands-on element in learning science in the classroom. Pruet (2015) cited that students were not engaged with in-depth STEM learning process due to poorly conceptualized STEM curricula. In the context of learning science in Malaysia, such an approach may entail a learning module that integrates both the theoretical and practical elements. Furthermore, such a module may have to include the element of creativity and innovation to make learning science fun among students and to help teachers develop creative teaching ideas.

In fact, the need for such an approach is in line with the principles of situated cognition theory, underscoring the notion that understanding how skills and knowledge can be applied is as essential as learning the knowledge and skills themselves, where both physical and social elements of a learning activity are important to the learning process (Kelley and Knowles 2016). Awad and Barak (2018) asserted that hands-on lab work played a vital role in promoting meaningful learning process among the students. While, Song (2018) found that students' learning has improved in getting better understanding of conceptual knowledge via hands-on project based learning. Accordingly, the activity itself will lead the student to learn the required knowledge and, at the same time, obtain the appropriate skills, effectively making the learning process realistic and relevant (Kelley and Knowles 2016).

Constructivist theory suggests that learning is a non-linear and learner-centered activity. While, social constructivists emphasized that individuals who construct their meaning of knowledge learned through interactions with other learners. These theories propose that it is through dialogue that individuals create meaning and modify their understanding of the world (Richardson 2012), which is in-line with the aim of the developed modules for this study.

Premised on these theoretical underpinnings, it is essential for teachers to use a teaching approach that infuses hands-on element in the teaching and learning process of science subjects. Learning modules that integrate both the theoretical and practical elements for learning science can be developed and used in such approach. This way of teaching will lead to inquiry-based teaching, which is deemed to be one of the effective way for teaching STEM in classrooms. Inquiry-based learning increases the students' learning opportunities, and the teachers who teach science need to utilize this learning technique efficiently (Hall and Miro 2016). Moreover, according to Roche and Prendergast (2016), inquiry-based learning can sustain and nurture students' interest in learning STEM subjects.

This study aims to evaluate the effectiveness of hands-on educational modules to help students learn the topics of stability and electromagnetism by focusing on an innovative teaching kit to attract students' attention to learn science through activities. An educational kit that is known as My Teachers TryScience (MYTTS) that was developed specially for Malaysian science education. In fact, Teachers TryScience is an initiative launched by IBM to promote science education. Essentially, the developed modules consist of science materials of the topics stability and electromagnetism of the Form-Two (Chapter 9) and Form-Three (Topic 1.9) science subjects, respectively. These topics were chosen because the learning of all the relevant concepts involved would entail sufficient hands-on activities where students could participate to develop sound conceptual knowledge of the subject matters.

Arts and Stability Card (A&S Card) educational kit was developed to help students to learn and apply the appropriate scientific concepts in real-life situations. Using such a novel educational kit, students would learn the concept of a building's "critical load," which represents the weight at which the building's structure would collapse. Students would also learn that a building's ideal structure needs to both strong and lightweight, the combination of which is extremely difficult to achieve.

As acknowledged by teachers, one of the science topics that many students struggled with is electromagnetism as the concepts involved are not easily discerned given their complex and highly abstract nature (Rohadi 2016; Mohd Salleh 2008). In principle, an electromagnet is a temporary magnet where magnetism is generated by electric current flowing through a conductor, such as an electric wire (Nicolaide 2012). The magnetic field is only produced when the current flows through the conductor, and this field will disappear when the current stops flowing through the conductor.

In Malaysia, the topic of electromagnetism is introduced in the syllabus of the Form-Three science subject (involving students aged fifteen) under Topic 1.9, where students need to develop a sound understanding of electromagnetism (Ministry of Education 2011). In this topic, students learn the theoretical aspects and principles of electromagnetism, such as the electromagnetic strength of magnets and draw a diagram of an electromagnet circuit. Therefore, this study was carried out with the main aim to assess the effectiveness of the MYTTS modules in the classroom setting to help students learn all the concepts of the two selected topics of the science subjects.

Arts and Stability Cards Module

In this study, a teaching kit named Arts and Stability Card (A&S Card) was developed consisting of fifteen pieces of interactive, colorful cards. The word "Art" was coined to emphasize students' artistic skills in building structures using such cards. Specifically, the A&S Card introduced students to the concept of a critical load, which is the maximum weight that a building structure can support, beyond which such a structure could collapse. Using this novel card, students were instructed to build a double- or single-story structure that could hold a 500ml bottle (filled with water) or to design a base area that could hold a textbook. Interactively, they could observe the ability of such structures to support the weights of exerted by such objects and to redesign the building if such structures collapsed under such weights. Through this interactive activity, as presented in Figure 1, the students were able to test the building design and explore the factors that contributed to the stability of the building.

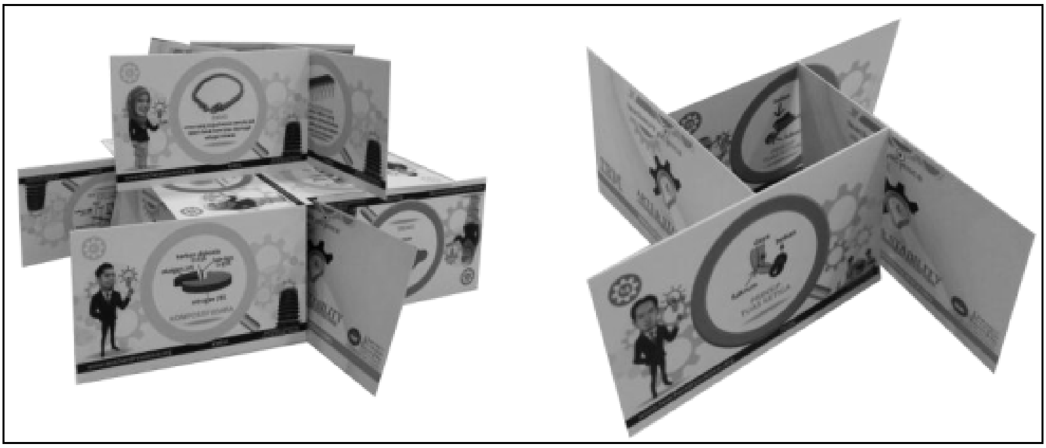

Figure 1: A&S Card Kit
Source: Balakrishnan et al. 2019

Magnobolt Module

The Magnobolt module consists of bolts and wires of different sizes and colors with battery holders, paper clips, and plastic holders. Essentially, Magnobolt introduced students to the use of bolts as the core component in developing an electromagnet. To create an electromagnet, students were required to coil the conducting wires around a bolt and to turn it into a solenoid by connecting the wire to a battery, which effectively helped create a simple working electromagnet. The electromagnet was then brought near to the paper clips, as shown in Figure 2, and the numbers of paper clips attracted by the electromagnet were recorded. Through this activity, students were able to explore the factors that might affect the strength of the electromagnet by varying the number of coils, the diameter of the core, type of core, and the amount of current, all of which are critical factors emphasized in the syllabus of the Form-Three science subjects. Students were able to manipulate these factors and observe their effects, which ultimately helped them to think creatively about factors that would affect the strength of an electromagnet.

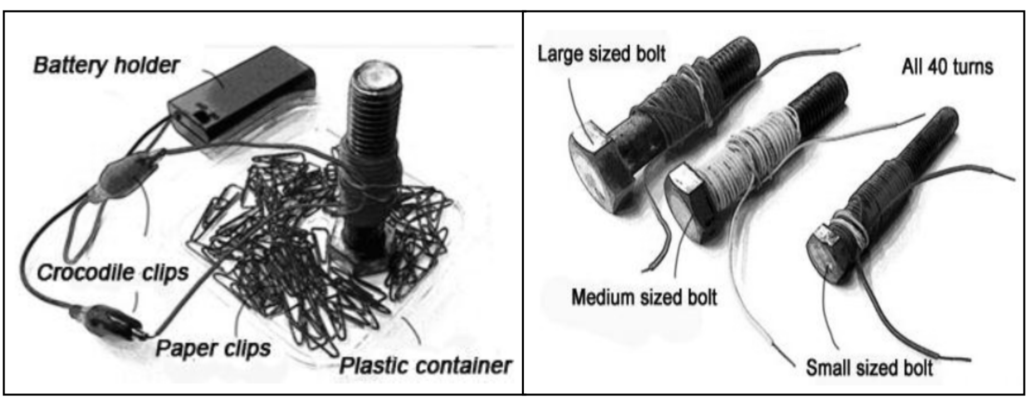

Figure 2: Magnobolt Kit
Source: Balakrishnan et al. 2019

Methodology

This study used the quasi-experimental design, which is a research design based on an experimental approach involving a control group and an experimental group (Campbell and Stanley 2015). Both groups consisted of secondary school students who had similar academic achievements in science, which were moderate based on their mid-term test scores, ranging from 65 to 75 over a total of 100 marks. For the learning treatment, the control group used the conventional learning approach while the experimental group used the MYTTS kits.

Sampling Process

Using the cluster sampling technique, twenty-seven schools from ten districts in the state of Perak, Malaysia were recruited to assess the effectiveness of the modules. The teachers who had undergone the Training of Trainers program were selected and divided into two groups, namely the control group and the experimental group. For the assessment of the A&S Card module, seven schools were selected to be in the control group, and likewise, another seven schools were assigned to the experimental group. For the Magnobolt module, six and seven schools were assigned to the control group and experimental group, respectively. For the learning treatments, 400 sets of MY Teachers TryScience modules (Magnobolt and Arts & Stability Cards) were prepared to be distributed to all the selected schools for assessing the effectiveness of MY TTS module in the classroom.

Research Instrument

In this study, two research instruments, comprising twenty-one test items, were developed for the teachers to evaluate the effectiveness of the Arts & Stability Cards and Magnobolt modules. Specifically, the instruments were used for the pretesting and posttesting of the Arts & Stability Cards module and the Magnobolt module for the topic of stability and the topic of electromagnetism, respectively. Data were collected through these tests in terms of test marks, the total of which was normalized to 10. Furthermore, the reliability testing of both instruments for the Arts & Stability Cards module and Magnobolt module involved twenty-three students and thirty-one students (who did not participate in the learning treatments), respectively. The computed Cronbach's Alpha coefficients were moderately high, ranging from .60 to .78, suggesting sound internal consistency of these instruments.

Results and Discussion

For the learning of the topic of stability using the Arts & Stability Cards module, the numbers of students in the control and experimental groups consisted of forty-eight students and fifty students, respectively. For the learning of the topic of electromagnetism using the Magnobolt module, the numbers of students in the control and experimental groups consisted of seventy-nine students and seventy-eight students, respectively. The analysis of the posttest scores of the control group and the experimental group after using such novel modules revealed several interesting results. In the control group, the students were went through teacher-centered teaching whereby the teachers taught the subjects matter employing traditional teaching technique—using textbooks only—without any hands-on activities.

For the topic of stability, the analysis showed that the mean scores of the experimental group and the control group were 9.32 (SD = .58) and 9.17 (SD =.85), respectively, indicating that the former performed slightly better than the latter. Table 1 summarizes the mean scores of the topic of stability of the experimental and control groups.

Table 1: Mean Scores of the Topic of Stability of the Experimental and Control Groups

Group	Posttest scores of the topic of stability		
	Mean	*SD*	Std. Error
Experimental (n = 50)	9.32	0.58	0.083
Control (n = 48)	9.17	0.85	0.124

Source: Balakrishnan et al. 2019

The researchers performed the t-test to determine if there was a significant difference in the posttest scores between the two groups. This test revealed that such a difference was significant, suggesting that the MY Teachers TryScience's Arts & Stability Cards module has a profound impact on student learning of the topic of stability. Table 2 summarizes the difference in the posttest scores of the measures between the experimental and control groups that used the Arts & Stability Cards module.

Table 2: Posttest Scores of the Topic of Stability of the Experimental Group and the Control Group

Group	*t*	*df*	Sig.(2-tailed)	Mean difference	95% CI of the difference	
					Lower Mean	Upper Mean
Experimental	112.28	49	0.000*	9.32	9.15	9.49
Control	73.94	47	0.000*	9.16	8.92	9.42

$*p<0.001$

Source: Balakrishnan et al. 2019

Likewise, for the topic of electromagnetism, the same descriptive analysis showed that the mean scores of the experimental group and the control group were 4.69 (SD = 2.42) and 3.82 (SD =1.68), respectively. Again, this analysis showed that the former performed relatively better than the latter. Table 3 summarizes the mean scores of the topic of electromagnetism of the experimental group and the control group.

Table 3: Mean Scores of the Topic of Electromagnetism of the Experimental and Control Groups

Group	Posttest scores of the topic of stability		
	Mean	*SD*	Std. Error
Experimental (n = 50)	4.69	2.42	0.27
Control (n = 48)	3.82	1.68	0.19

Source: Balakrishnan et al. 2019

Similarly, the same t-test was performed to determine if there was a significant difference in the posttest scores between the two groups. As anticipated, the test revealed that the difference in the learning performances for the topic of electromagnetism between the two groups was significant, which favored the former. This finding suggests that MY Teachers TryScience's Magnobolt module has a profound impact on student learning of the topic of electromagnetism. Table 4 summarizes the difference in the posttest scores of the measures between the experimental group and the control group that used the Magnobolt module.

Table 4: Posttest Scores of the Topic of Electromagnetism of the Experimental Group and the Control Group

Group	*t*	*df*	Sig.(2-tailed)	Mean difference	95% **CI** of the difference	
					Lower Mean	Upper Mean
Experimental	17.09	77	0.000*	4.69	4.15	5.24
Control	20.16	78	0.000*	3.823	3.45	4.20

*$p<0.001$

Source: Balakrishnan et al. 2019

Results from the posttests showed that the students in the experimental group attained higher learning performance in the two topics compared to that of the control group. Arguably, the two modules provided the students with ample opportunity to learn the highly abstract concepts of electromagnetism and stability more meaningfully, since they could learn through hands-on activities by applying the concepts in a real-life situation. Such promising results strongly suggest that the two modules play a significant role in assisting students to gain a sound understanding of the concepts of stability and electromagnetism. These findings may help inform teachers or instructors of the importance of diversifying their teaching practice. The scientific skills that are connected with the topic of the subject matter need to be embedded in the teaching and learning process. Students' understanding while learning the subject matter could be enhanced through the hands-on activities using the developed modules in the classroom. At the same time, the developed modules facilitate the students to gain better knowledge and skills on magnetism and stability.

As demonstrated in this study, the use of learning modules (such as the MYTTS modules) that promote hands-on activities could help students to become consciously aware of the connections of relevant scientific concepts to real-life situations, effectively helping them to better understand the subject matter better and thus improve their learning performance. More importantly, the learning activities accorded by such modules enable students to participate actively and collaborate intimately with team members in the application of newly learned concepts that help enhance students' conceptual knowledge of STEM subjects (Balakrishnan and Azman 2017). Learning through novel modules that expose students to the hands-on activities would help increase their awareness of the practical applications of the scientific concepts in real-life situations. Ultimately, in the long run, students would build a deep interest in learning STEM subjects that would motivate them to further explore the world of science (Demircioğlu and Sezgin Selçuk 2016).

Conclusion

In conclusion, the use of innovative learning modules, such MY TTS provide hands-on activities in the real-world context. The students who participated in collaborative learning had their understanding of relevant scientific concepts profoundly impacted. These scientific concepts are not easily learned given the nature of the subjects, which are inherently abstract and complex. Hence, such novel learning modules should become an integral part of the teaching and learning process of science subjects, with which students could actively engage in hands-on learning activities that improve not only their learning performance but also their interest and motivation in learning STEM subjects. In fact, such learning is in line with the twenty-first century's educational needs that demand effective learning approaches to help students become more creative and articulate in dealing with new challenges.

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ABOUT THE AUTHORS

Balamuralithara Balakrishnan: Associate Professor, Faculty of Art, Computing & Creative Industry, Sultan Idris Education University, Tanjung Malim, Perak, Malaysia.

Mohamed Nor Azhari Azman: Associate Professor, Faculty of Technical & Vocational, Sultan Idris Education University, Tanjung Malim, Perak, Malaysia.

Aisyah Mohamad Sharif: Senior Lecturer, Faculty of Science & Mathematics, Sultan Idris Education University, Tanjung Malim, Perak, Malaysia.

Mohd Ikhwan Hadi Yaacob: Senior Lecturer, Faculty of Science & Mathematics, Sultan Idris Education University, Tanjung Malim, Perak, Malaysia.

Haniza Hanim Mohd Zain: Associate Professor, Faculty of Science & Mathematics, Sultan Idris Education University, Tanjung Malim, Perak, Malaysia.

Parmin: Associate Professor, Fakultas Matematika & Ilmu Pengetahuan Alam, Universitas Negeri Semarang, Semarang, Indonesia

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