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Short Communication

Students' Knowledge in Science: An Evaluation via Hydroponic Kit

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ABSTRACT

Every year, high school students response to choosing a science stream has indicated a declining pattern. It may be due to the lack of technical application of science that students cannot foresee, thus preventing them from having a clear vision of how science and technology could greatly help daily human life. The study aims to assess the knowledge of high school students through STEM education via a project-based learning method using the hydroponic kit. Seventy students from a government school in Kota Bharu, Kelantan, Malaysia, participated in this study. The questionnaire was then evaluated based on the scores and displayed improvement. The mean score for the pre-test of general knowledge was M=3.8857, SD=1.41977, and then it increased to M=6.1857, SD=1.21932 for the post-test. In addition, the mean score for the pre-test of hydroponic system advantages was M=6.2000, SD=1.93068, which increased to M=8.8286, SD=0.65875 for the post-test. Meanwhile, the mean score for the pre-test of disadvantages of the hydroponic system was M=7.2571, SD=2.21121, subsequently increasing to M=9.4286, SD=0.73369 for the post-test. Finally, the mean score for the pre-test of practical knowledge was M=9.3429, SD=2.51307, and then increased to M=15.0571, SD=1.84065 for the post-test. Students' responses to the tests indicated that their interest in the field of science has increased through their involvement in the hydroponic kit project.

Keywords: Hydroponic kit, knowledge, pre and post-test questionnaire, project-based learning, STEM education

INTRODUCTION

Nowadays, STEM is not familiar as it is an essential field needed by a country to develop and thus achieve a high level of modernisation. Western countries, such as the United States, Switzerland, United Kingdom, Sweden, Netherlands, Ireland, Germany, and Denmark, as well as Asia and the Pacific, such as Singapore, Republic of Korea, and China, have all achieved a high level of progress, which symbolised modernisation (United Nations Conference on Trade and Development, 2021). These nations have applied science and technology in developing and achieving advancement in their respective countries. Since 2003, the United States has been mobilising STEM education to increase science and technology competitiveness. Therefore, it is not surprising that the country has reached a high level of development. STEM education focuses on physical learning through skill-based activities such as investigation, designing, problem-solving, teamwork, and communication. Baran et al. (2015) mentioned that STEM educational activities approach science, technology, engineering, and mathematical disciplines using the knowledge and skills of the 21st Century. In the 21st Century, creativity is an important skill that students need to possess (Stehle & Peters-Burton, 2019); hence, this skill guarantees them a brighter future (Hanif et al., 2019). The alignment of the 21st Century learning components with the 21st Century learning design rubrics has also indicated creativity and innovation as the two main domains of modern-day learning (Stehle & Peters-Burton, 2019). Since the job market has been shifting daily, students need to be well equipped with essential knowledge that is gained theoretically and the actual living skills into which STEM is being integrated.

In general, STEM education is an effort to integrate science, technology, engineering, and mathematics disciplines by correlating the content of a unit or subject with real-time problems. A more modern definition states that STEM education is an interdisciplinary teaching method that integrates science, technology, engineering, mathematics, and other knowledge, skills, and beliefs into these disciplines (Baran et al., 2016; Koul et al., 2018; Thibaut et al., 2018). Using the STEM approach, students can solve various problems and become innovators, inventors, independents, logical thinkers, and technologically literate people (Widya et al., 2019). Therefore, STEM education is a term that refers to teaching and learning in STEM subjects, which is problem-solving with real-world problems that integrate many other disciplines and skills, such as science, technology, mathematics, and engineering. In recent years, we have been stunned by the decline of students choosing science, technology, engineering, and mathematics (STEM) subjects in schools and higher learning institutions in Malaysia (Ismail et al., 2019). Nowadays, students are less interested in science. They consider science difficult as compared to accountancy and literature. In addition, they may be given less practical exposure to science that can be found around them, which has greatly helped to facilitate daily human work and brought many benefits. It is a matter of great concern to the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) Malaysia. The ministry is responsible for sustainable energy, wealth creation through science and technology, and environmental conservation and must ensure that such knowledge reaches every community and can be adapted. If such a situation does not occur, our country will experience a shortage of skilled and talented human resources in science and technology, as the industry requires.

Recently, the emphasis on STEM in Malaysian secondary schools has increased to provide students with the skills needed in the industry and future careers (Razali, 2021). Therefore, a project-based learning model is deemed suitable to meet these skills because it integrates STEM (Lou et al., 2011). This study aims to assess students' knowledge in school before and after exposure to the hydroponic kit application based on pre-test and post-test questionnaires. The study will also evaluate students' interest in STEM subjects, which incorporate problem-solving skills in real-world situations, and integrate many other disciplines and skills, such as science, technology, mathematics, and engineering. This learning method can increase students' knowledge performance and thus nurture students' interest in STEM, produce quality students in terms of thinking style, creativity, and innovativeness, and become bold enough to face future challenges.

MATERIALS AND METHODS

The study was conducted at a government school in Kota Bharu, Kelantan, Malaysia, from February until November 2020. The selected school was under a pilot project led by the National STEM Association (NSA), which was to be an example for other schools in Kelantan to uphold STEM. The study has conducted five programmes/meetings between the mentors and mentees over nine months. In the meetings, students were introduced to hydroponics and its cultivation methods on (1) how to install a hydroponic kit system, (2) how to prepare media, (3) how to sow seeds, (4) how to measure fertiliser, and (5) to harvest crops). In the meetings, students were also exposed to problem identification and how to solve problems related to hydroponics so that students would gain knowledge and interest in science. The study subjects were 70 conveniently selected students based on availability and voluntariness, which consisted of 36 male students (51.4%) and 34 female students (48.6%).

The students were required to answer a pre-test questionnaire before the programme started and a post-test questionnaire after the programme ended. The two questionnaires contained 26 questions, comprising a similar set of questions related to project-based learning: hydroponic kit. The questionnaires were trialled, tested, and sent for revision to ensure item comprehension, wording, and adequacy of responses. The content validity was applied by consulting a small sample of panels and experts in a particular area to pass judgement on the suitability of selected questions (Sekaran & Bougie, 2010). The example of questions used and validated by three panels within the expert area of study are (1) what are the four basic requirements for tree growth? (2) what is hydroponic cultivation? (3) why was hydroponic cultivation introduced? The Likert scale was applied from 1–5 (strongly disagree to strongly agree). The experts provided a score with an average of 4.7, which indicated that the experts strongly agreed with all the questionnaire items. The purpose of content validity was to get feedback concerning the suitability, content, layout, and adequacy of questions designed based on the literature review (Wee & Abas, 2015). For statistical analysis, paired student t-test was used to compare the pre-test and post-test scores, whereby *p* values were calculated using the Statistical Package for the Social Sciences (SPSS) software Version 26. Paired student t-test was utilised to assess school students' knowledge before and after being exposed to hydroponic kits on pre-test and post-test questionnaires. The paired student t-test could help assess the variables, namely knowledge_general, knowledge_advantages, knowledge_disadvantages, and knowledge_practices.

RESULTS

A total of 70 students participated in the pre-test and post-test. The number of correct post-test responses was significantly higher ($p<0.01$) than pre-test responses (Table 1). However, some items had similar scores for the pre-and post-tests, and some had a large difference in scores for the pre-and post-tests. It was due to the types of questions and students' level of knowledge and understanding before and after they were exposed to the project. There were four sections in the questionnaire: (1) Knowledge_General: Q1: Basic requirements of tree growth; Q2: Definition of hydroponic plants; Q3: The purpose of hydroponic technique introduction; Q4: Types of plants suitable for hydroponic techniques; (2) Knowledge_Advantages: Q5: High-quality production; Q6: Easy to install; Q7: Low cost; Q8: Balanced nutrient; Q9: Suitable for all types of crops; (3) Knowledge_Disadvantages: Q10: Needs a lot of electricity; Q11: Not environmental-friendly; Q12: Susceptible to disease; Q13: Need frequent watering; Q14: Less clean; (4) Knowledge_Practices: Q15: Hydroponic care measures; Q16: Steps provide hydroponic plants; Q17: How to suit hydroponic plant seedlings; Q18: Effects of exposure to rain; Q19: Causes of hydroponic plants wither and die; Q20: Hydroponic crop risks; Q21: A suitable place for hydroponic plants; Q22: Hydroponic plant media; and Q23: Characteristics of hydroponic media. The overall mean scores indicated a significant improvement in post-test scores compared to the pre-test scores (Table 2).

Table 1
Student's pre-test and post-test responses (n=70)

Questions	Correct responses (n)		Significance value
	Pre-test	Post-test	
Q1.	70	70	
Q2.	44	64	
Q3.	26	59	
Q4.	65	69	
Q5.	56	70	
Q6.	10	70	
Q7.	29	70	
Q8.	64	70	
Q9.	58	70	
Q10.	41	70	
Q11.	54	70	
Q12.	47	70	
Q13.	58	70	
Q14.	55	70	
Q15.	68	70	
Q16.	66	70	
Q17.	27	70	
Q18.	43	64	
Q19.	70	70	
Q20.	66	69	
Q21.	39	70	
Q22.	66	70	
Q23.	59	70	
Mean±SD	51.35±16.51	68.91±2.76	t=5.339, *p*-value=0.000*

Note: *Significance levels at 0.1, 0.05, and 0.01

Table 2

Comparison of the student's scores in the pre-and post-tests

Questions	Mean±SD			t	df	*P*-value
	Pre-test	Post-test	Increase			
Knowledge_General	3.89±1.41	6.19±1.22	2.30±1.62	11.891	69	0.000*
Knowledge_Adv	6.20±1.93	8.83±0.66	2.63±2.08	10.576	69	0.000*
Knowledge_Dis	7.26±2.21	9.43±0.73	2.17±2.34	7.763	69	0.000*
Knowledge_Practices	9.34±2.51	15.06±1.84	5.71±3.31	14.441	69	0.000*

Note: Results are expressed as the mean and standard deviation of the total scores obtained in the pre-and post-tests. Significant (*P*-value) was obtained using a paired samples *t*-test.
*Significance levels at 0.1, 0.05, and 0.01.

The pre-and post-tests were the instruments utilised in measuring the study effect. There was a significant difference in the scores for the pre-test of Knowledge_General (M=3.89, SD=1.42) and post-test of Knowledge_General (M=6.12, SD=1.23); t(69)=11.99, *p*=0.00. Other than that, there was also a significant difference in the scores for the pre-test of Knowledge_Advantages (M=6.20, SD=1.93) and the post-test of Knowledge_Advantages (M=8.83, SD=0.66); t(69)=10.58, *p*=0.00. A significant difference was also found in the scores of the pre-test for Knowledge_Disadvantages (M=7.26, SD=2.21) and the post-test of Knowledge_Disadvantages (M=9.43, SD=0.73); t(69)=7.76, *p*=0.00. Finally, a significant difference was also discovered in the scores of the pre-test for Knowledge_Practices (M=9.34, SD=2.51) and the post-test of Knowledge_Practices (M=15.06, SD=1.84); t(69)=14.44, *p*=0.00. The approach of teaching and learning adopted in this project through the application of the hydroponic kit has improved learning ability and increased knowledge received, which were indicated by the positive response from students. Most students agreed that the Mentor-Mentee of a STEM project-based learning programme through the application of the Hydroponic Kit could help improve their focus and performance, as it is considered a trigger factor to be attentive and push themselves to be more in-depth in their study.

DISCUSSION

The purpose of the study is to see whether the initial test given before the learning process can be improved in the final test. This study assesses school students' knowledge based on the Hydroponic Kit Project. Kanadli (2019) denoted that the advancement in science and technology that educational institutions now require does not only train people who are ready with the knowledge but also trains people who know how to access knowledge and generate new information through their application knowledge. STEM has been characterised as working in the context of complex phenomena or situations on assignments requiring students to apply knowledge and skills to various disciplines (Honey et al., 2014). The Hydroponic Kit Project covered all the elements found in science, technology, engineering, and mathematics (STEM). It is in line with Hashim et al. (2020), who created a prototype of a water level warning in project-based learning, which was also integrated with STEM. It was supported by Lou et al. (2011), who stated that the STEM-based learning model incorporates all STEM elements into curriculum design.

The data from this study has indicated that STEM project-based learning can improve the general knowledge of school students. The mean score for the pre-test of general knowledge was (M=3.8857, SD=1.41977) and then increased to (M=6.1857, SD=1.21932) for the post-test (Table 2). School students were likely to have less direct or indirect exposure to science projects or other advanced materials adopted or applied in their environment. In traditional classrooms, teaching and learning are dominated by teachers, whereby students have minimal opportunity to express their opinions and ideas (Tytler & Aranda, 2015), thus reducing student interaction and limiting them from expressing their views (Chua et al., 2017). Dugger (2010) highlighted that a STEM project-oriented curriculum had been used as a strategy, offering students the opportunity to consider real-world concerns focused on interdisciplinary topics. Moreover, Jeong and Kim (2015) suggested that effective teaching occurs when students are given learning opportunities to demonstrate, adapt, modify, and transform new knowledge to meet the needs of new contexts and situations. Therefore, such learning methods can add to and improve the school students' general knowledge. Figure 1 shows a briefing and discussion session on the Hydroponic Kit Project between mentors of Universiti Malaysia Kelantan (UMK) students and their mentees from a government school in Kota Bharu, Kelantan. This session was held to develop and cultivate creative thinking among students (Munandar, 1999). Creative thinking can help youngsters to have a fresh perspective from the normal ones instilled in the classroom lesson. It is where the impression of "thinking out of the box" can be instilled through a live hands-on experience conducted by the students with teachers' supervision and participating mentors. Barak and Assal (2018) and Lee et al. (2019) supported this by stating that high-level thinking skills, such as problem-solving, critical thinking, and creative thinking, are key targets in STEM learning in Asia.

Figure 1. Briefing sessions and discussions between mentors and mentees regarding the hydroponic kit project

The study has also found an increase in student's knowledge of the advantages and disadvantages of exposed hydroponic systems. The mean score for the pre-test of hydroponic system advantages was M=6.2000, SD=1.93068 and then increased to M=8.8286, SD=0.65875 for the post-test. Meanwhile, the mean score for the pre-test of disadvantages of the hydroponic system was M=7.2571, SD=2.21121, which then increased to M=9.4286, SD=0.73369 for the post-test. It shows that the students initially needed to learn more about the advantages and disadvantages of the hydroponic system. However, when given exposure to theory and practice, they were now aware of the importance and benefits of hydroponic systems. One of the outcomes of interest in the pilot project was curiosity. Shah et al. (2018) highlighted that curiosity motivates behavioural exploration and finding answers to the unknown. Banning and Sullivan (2011) supported this argument, stating that the curiosity of young students is very high, as it is a key component that drives exploration and refinement of their perceptions while gathering information and learning from the environment. McGillivray et al. (2015) introduced several affective variables, such as curiosity and interest, and potential rewards associated with remembering interesting information in the future. From the context of sustainability, curiosity is an important driver of inquiry learning and is considered fundamental in scientific literacy. Since exploration, discovery, innovation, and invention often stem from curiosity, there is a strong fundamental contribution of curiosity to sustainability-related issues (Ernst & Burcak, 2019).

Finally, there was a significant increase in practical knowledge, whereby the mean score for the pre-test was M=9.3429, SD=2.51307, and then increased to M=15.0571, SD=1.84065 for the post-test. Therefore, practice-based learning is very suitable for students so they can go to the field and get their hands dirty by doing activities rather than just sitting in class, which reduces students' interaction and limits their views (Heng et al., 2017). Amongst the activities is the installation of hydroponic equipment (Figure 2), where the students were exposed to elements of engineering and technology found in the design and technology used. The equipment consists of pipes (large and small sizes), basins, and water pumps. The installation of such equipment requires the creativity and thinking skills of students. Next was the preparation of media (Figure 3), where the elements of scientific knowledge were revealed to students: how to select the correct media such as cocopeat, Rockwool, sponge, and others. Such selection also plays an important role in absorbing water and nutrients and adapting to the plants to be planted. The following process measured and mixed the fertiliser (Figure 4). For this activity, mathematical elements were exposed to the students. The materials needed were fertilisers A and B, beakers, and syringes. Fertilisers must be mixed in proportions to ensure that the plants have the needed nutrients. The last process was to lay the seeds (Figure 5). Figure 6 shows the hydroponic kit that yielded results. These activities incorporated the STEM elements practised in Malaysia and other developed countries.

Figure 2. The picture shows students installing hydroponic equipment

Figure 3. The picture shows a demo of media preparation by STEM instructors

Figure 4. The picture shows students being taught to mix fertiliser with the correct dosage

Figure 5. The picture shows students sowing seeds into plant pots

Figure 6. The picture shows a hydroponic kit that has borne fruit

Overall, the mean score for all knowledge in this study indicated an improvement after applying STEM activities based on the Hydroponic Kit Project in secondary school. Grossnickle (2016) supported the notion by defining curiosity as the desire for new knowledge, information, experience, or stimuli to bridge an unknown gap. Additionally, the encouragement received from mentors and teachers is also crucial in determining the effectiveness of STEM Mentor-Mentee project-based learning.

Therefore, such learning methods are the learning of the new millennium or so-called new norms that need to be applied in all secondary and primary schools in the country. Hopefully, this method can attract students to choose science as their main choice to further their studies to a higher level. There has been a drastic decline in the selection of students in science majors at the tertiary level in recent times due to the lack of such learning approaches, which is of great concern to universities and industry. University and industry collaboration are critical in accelerating the effectiveness of STEM implementers in schools (Tumuti et al., 2013). Anwar et al. (2018) and Yuk (2008) mentioned that such collaboration could provide teachers and students with a broad knowledge of real-life contexts that could enrich the teaching and learning process and equip students to perform future career development. It can prepare students to face the advancement in science and technology and drive the country towards being a developed and competitive nation in the future (Hanif et al., 2019).

CONCLUSION

In conclusion, the Mentor-Mentee of STEM project-based learning method using the hydroponic kit can increase students' knowledge and understanding of science, technology, engineering, and mathematics (STEM). It can be seen through the mean score for all knowledge in this study which has indicated an improvement after applying STEM activities based on the Hydroponic Kit Project in secondary school. Grossnickle (2016) supported the notion by defining curiosity as the desire for new knowledge, information, experience, or stimuli to bridge an unknown gap. Such learning methods can also indirectly increase creativity and innovation and apply thinking skills to students so they can be prepared for future challenges. It is hoped that such learning methods can cultivate and attract students from primary and secondary levels to choose STEM majors when they move to higher education institutions later. Other than that, the support system in the educational system should also play an important role in encouraging students to be more involved with STEM-based education. Teachers, specifically, play an essential role in dictating the aftermath of the young generation (Shaharuddin et al., 2020). The noble profession, in precise, is also a key player in the organisational setting of schools due to their close engagement with students. Therefore, teachers and parents must work hand in hand to ensure that students nowadays are more enthusiastic and passionate about making STEM the number one choice in their future endeavours. With the advancement of education, the future generation will be much more aware of the measures that need to be taken in facing uncertain conditions of today's new way of life and the pandemic.

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