The Effectiveness of the STEM Kid Module for High and Moderate Achievers Elementary School Children Towards Scientific Literacy

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Abstract: The aim of this research is to determine the effectiveness of the 'STEM Kid Module on the scientific literacy of fifth-grade students in the 'Energy' topic. The module was developed based on the combination of constructivism and constructionism as a fundamental learning theory. Meanwhile, the STEM Kid instructional phase was formed using a STEM integrated approach that included engineering design processes and inquiry-based science learning. A quasi-experimental design was used to assess the effectiveness of the STEM Kid Module. This study included 116 children, 61 of whom were high achievers and 55 of whom were moderate achievers. Two elementary schools using the STEM Kid Module were selected as the treatment group, while another school using conventional teaching approach as the control group. Data for this study were gathered by a scientific literacy test that included (i) scientific knowledge, (ii) science process skills, and (iii) daily science application. Results from repeated measurements MANOVA analysis revealed a significant difference in scientific knowledge and daily science application between groups. The study's implication was that the use of the STEM Kid Module through a STEM integrated approach can be implemented in elementary school science teaching and learning for children of varying levels of achievement.

Keywords: Science education, STEM, Engineering design process, Children, Scientific literacy

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Introduction

Since the late 1950s, the policy of developing a scientifically literate society has been emphasized (DeBoer 2000; Ogunkola 2013). However, as reported by the Ministry of Science, Technology, and Innovation (MOSTI, 2010) and the National Science Board (NSB, 2014), it is worrisome that surveys conducted both domestically and internationally indicate that the level of scientific literacy in the community is still quite low. Since the survey was conducted nearly two decades ago by the Malaysian Science and Technology Information Centre (MASTIC 2014), this trend has persisted. Therefore, the development of this society should not be disregarded, as society is partially comprised of them who work in STEM fields should be literate, intelligent, and scientifically literate (Lilia, 2013).

The attempt to create a scientifically literate society should begin early in primary education. Piaget explained that at this stage, children are at the concrete operational level (Hurlock, 1990), which indicates that their cognitive aspects are developing. It was discovered that students are capable of learning and comprehending the fundamental concepts of science (Eshach, 2006). This can be achieved through an efficient teaching and learning process founded on scientific concepts. However, students are still less likely to engage in authentic science learning (Harlen 1999; Eshach 2006). This is due to the fact that the learning process of students is more focused on theoretical understanding than practical work (Tseng et al., 2013), thereby reducing their opportunities to acquire appropriate science learning experiences. In the meantime, both theoretical knowledge and practise are required to acquire effective teaching and learning experiences.

Zohar et al., (2001) and Zohar and Dori (2003) explain that conventional teaching perception is preferred in learning by teachers because it is believed to be more effective and accepted by students with low and moderate intellectual abilities than methods requiring high intellectual abilities, such as inquiry and problem solving. If this method is implemented, it is anticipated that students will find learning difficult and burdensome because they lack the intellectual abilities necessary to deal with it. According to the analysis of the science subject' answer quality from the national primary school examination for the year 2019 (MEB, 2019), students with medium and low ability can only answer questions at the level of knowledge and comprehension but not at higher cognitive levels such as application. The implication is that the achievement gap between students with differing ability levels, that is, students with moderate, high, and low achiever levels, is growing. The approach by which students receive learning activities should not be differentiated based on their ability level.

Using constructivism and constructionism as the fundamental theories to support student learning, the STEM Kids module was developed in consideration of alternative teaching methods, specifically the STEM integration method, in response to the identified problems. Thus, the purpose of this study is to answer the following two research questions: (i) Can the STEM Kids module improve students' scientific literacy? and (ii) is there a significant difference in the improvement of scientific literacy among students with various achievers levels and groups?

STEM Kids Module

The STEM Kids module's instructional strategy and learning implementation process are fundamentally based on constructivism and constructionism. The theory of constructivism, which emphasises students constructing their own knowledge and rectifying misconceptions, is implemented using an inquiry-based learning strategy and the 5E instructional model (Bybee et al., 2006). Through the implementation of the five phases "engage", "explore", "explain", "elaborate", and "evaluate", this model aims at developing students' conceptual understanding. In the meantime, constructionism theory asserts that students can generate new ideas if they participate in the process of artefact creation. The TMI model (Martinez & Stager 2013), which is one of the engineering design processes, is used to implement the emphasis on problem-solving through design or problem-based learning through engineering practise. Through the implementation of the TMI model's three phases—"Think," "Make," and 'Improve," this model can help students generate new ideas and solve problems.

Based on the suggested learning theory and instructional model, they were combined to form the STEM Kids teaching model, an innovative teaching and learning phase. Figure 1 illustrates the implementation of learning within the STEM Kids module.

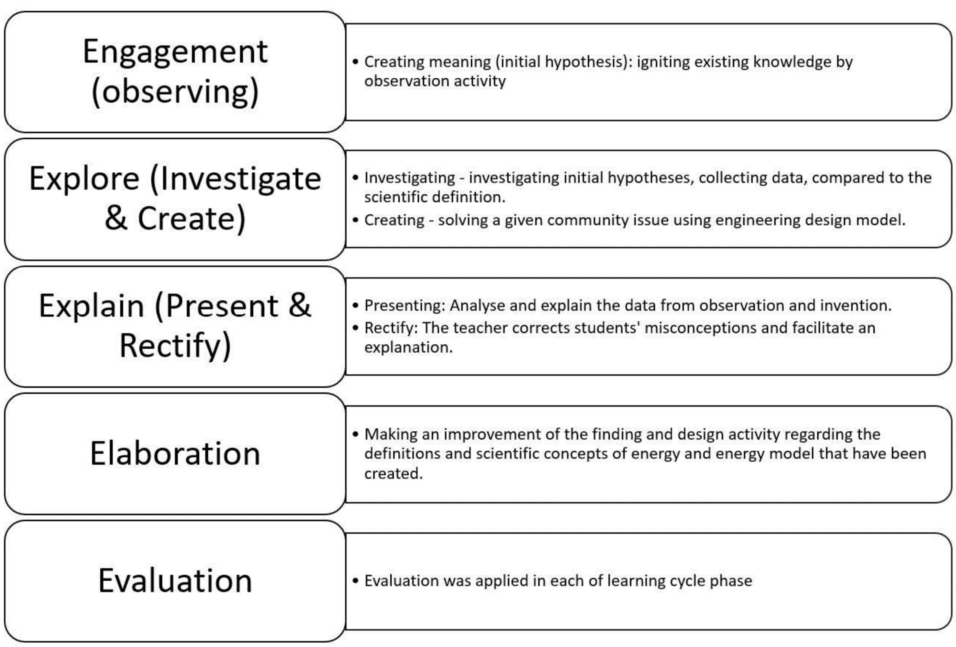

Figure 1. Teaching and learning process in the STEM Kids module

Method

Research design

A quasi-experimental design with a non-equivalent pre-test and post-test control group (Campbell & Stanley, 1963; Gall et al., 2003) was implemented to determine the effectiveness of the STEM Kids module in enhancing scientific literacy. The STEM Kids module was used in the treatment group. whereas the control group used conventional methods and textbooks. The study was conducted over the course of four weeks, which corresponds to the time period given in the teacher's lesson plan for teaching about energy topics.

Respondents

The study involved 116 fifth-year students from two different national primary schools in Selangor. The school is divided into two groups, with one group implementing the teaching and learning method through conventional inquiry. whereas the treatment group employs the STEM Kids module. The intervention was conducted in two classes comprised of high ability level students (the majority of students obtained high academic achievement, i.e., grade A with a science achievement score of 80 percent or higher) and medium ability level students (the majority of students obtained moderate academic achievement, i.e., grade B with a science achievement score between 65 and 79 percent) (MOE, 2016) (See Table 1). According to Han et al. (2014), the classification of the student's ability level is based on the student's achievement score. This study was carried out by two science teachers with more than five years of experience at their respective schools.

Table 1. Respondent profile

Achievers	Treatment group		Control group	
	n	%	n	%
High	32	56.1	29	49.2
Moderate	25	43.9	30	50.8
Total	57	100	59	100

Instrument

The scientific literacy instrument for the energy topic used in this study consists of three domains, namely: (i) scientific knowledge, (ii) science process skills, and (iii) daily science application.

(i) Scientific knowledge

Scientific knowledge is a multiple-choice test item. It is designed to assess students' mastery of knowledge and comprehension of science concepts, particularly the energy concept. Energy is one of the primary disciplines for fifth-year science students. There were 20 items in this test.

(ii) Science process skills

The science process skills (SPS) test in this study consists of 10 SPS aspects, including observing, classifying, measuring, and using numbers; predicting; communicating; interpreting data; defining operations; controlling variables; making hypotheses; and conducting experiments. This aspect was taken from Harlen (1999), Harlen and Elstgeest (1992), and MOE (2013). There were 15 multiple-choice items on the SPS test.

(ii) Daily science application

The daily science application test measured in this study consisted of three sub-topics in energy concepts for Year Five children: (i) energy forms and transformation; (ii) renewable and nonrenewable energy; and (iii) energy conservation. All of these questions were adapted from the instrument from PISA and Yager et al. (2009). These three open-ended questions were modified to form a question related to the application of scientific concepts at home, in the community, and in scientific phenomena.

Results

Based on the research questions, the analysis of the findings is divided into two major sections: (1) childrens' scientific literacy, and (2) a comparison of scientific literacy between groups.

(i) Childrens' Scientific Literacy

Descriptive statistics involving mean scores are used to answer the first research question, which is to identify the level of students' scientific literacy (See Figure 1).

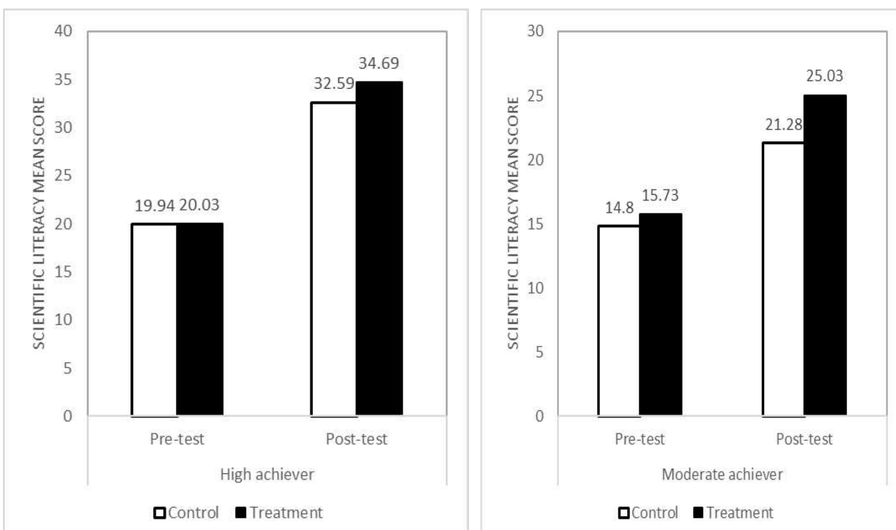

Figure 1. Childrens' scientific literacy for high and moderate achiever

Based on Figure 1, the pre-test mean score of the scientific literacy for high achiever students (x = 20.03;) and moderate achiever students (x = 15.73;) in the treatment group was higher than achiever students (x = 19.94;) and moderate achiever students (x = 14.8;) in the control group. Nevertheless, the mean score of the scientific literacy post-test for high achiever students (x = 34.69;) and moderate achiever students (x = 25.03;) in the treatment group outperformed the score of high achiever students (x = 32.59;) and moderate achiever students (x = 21.28;) in the control group. Based on the findings, both groups showed an increase in scientific literacy across time (from pretest to posttest).

(i) A Comparison of Scientific Literacy Between Groups

Inferential statistics involving repeated measurement MANOVA were used to answer the second research question, which was to identify the difference in students' scientific literacy between the control and treatment groups (see Table 2).

Table 2. Scientific literacy multivariate test

	Pillai trace value	F	df1	df2	p	Partial eta squared
Group	0.04	1.63	3	110	0.19	0.04
Achievers' Level	0.36	20.62	3	110	**0.00**	0.36
Group* Achievers' Level	0.01	0.49	3	110	0.69	0.01
Time	0.82	166.64	3	110	**0.00**	0.82
Time*Group	0.13	5.51	3	110	**0.00**	0.13
Time* Achievers' Level	0.20	8.93	3	110	**0.00**	0.20
Time*Group* Achievers' Level	0.03	1.20	3	110	0.31	0.03

The findings from the multivariate test of the scientific literacy domain in Table 2 show that there is a significant main effect of achievers' level at the $p<0.05$, which is $F(3,110) = 20.62$, $p = 0.00$, with a large effect size (partial eta squared = 0.36). Likewise, the main effect of time, which is the comparison from pretest and posttest mean scores of the scientific literacy domain without involving different group and achievers' level, shows a significant difference ($F(3,110) = 166.64$, $p = 0.00$), with a very large effect size (partial eta squared = 0.82). The interaction effect between time and group is also significant ($F(3,110) = 5.51$, $p = 0.00$), with a large effect size (partial eta squared = 0.13). Similarly, the interaction effect between time and achievers' level showed a significant interaction effect ($F(3,110) = 8.93$, $p = 0.00$), with a large effect size (partial eta squared = 0.20). This finding explains that the interaction effect of the two independent variables which were group and achievers' level affects the scientific literacy score individually at the time measurement from the pretest to the posttest. However, relating to this experimental study, the childrens' scientific literacy does not depend on the level of achievers' but the intervention given to them.

As a result of a significant interaction effect involving the interaction of time with group which is univariate test (within-subject effect), was analysed to determine which domain of scientific literacy demonstrated a significant difference. Based on Table 3, scientific knowledge ($F(1,112) = 8.28$, $p = 0.00$) and scientific application ($F(1,112) = 7.02$, $p = 0.06$) with a small effect size shows a significance difference at $p<0.05$.

Table 3. Univariate tests of the interaction effect of time and group on the scientific literacy domain

Scientific literacy domain	Sum of squares	df	Mean square	F	p	Partial eta squared
Scientific knowledge	36.61	1	36.61	8.28	**0.00**	0.07
Scientific application	35.26	1	35.26	7.02	**0.01**	0.06
Science process skills	6.86	1	6.86	1.76	0.19	0.02

In conclusion, the domains of scientific literacy, namely scientific knowledge and scientific application, demonstrate significant group differences. Moreover, the mean scores of these two groups increased linearly over the duration of the measurement time. However, the STEM Kids module-using treatment group demonstrated greater improvement than the control group. The group that utilises the module is more effective at enhancing scientific literacy, particularly scientific knowledge and application.

Discussion

The enhancement in students' scientific literacy as a result of the implementation of alternative teaching and learning is in line with previous research by Lestari et al. (2021) and Wen et al. (2020). The domain of scientific literacy that students acquire in terms of scientific knowledge, scientific application in daily life, and science process skills increases linearly and positively over time. This demonstrates that students may improve in these areas of scientific literacy after intervention, either conventionally or by using the module.

In terms of scientific knowledge and scientific application, students who gained experience using the STEM Kids module outperformed those who received conventional instruction. Even though the effect size is small, it is possible to conclude that the STEM Kids module is more effective than conventional instruction at improving students' scientific literacy, particularly in scientific knowledge and scientific application. This finding was consistent with previous research, such as Barth (2013) and Cotabish et al. (2013), indicating that alternative teaching or the implementation of interventions in teaching and learning science can increase science knowledge and application in life.

Due to the fact that students were exposed to the STEM integration approach, which comprises inquiry-based learning and problem solving through the engineering design process, the implementation of the STEM module was found to have an effect on the improvement of students' science knowledge. Solomon (1993) explains that alternative teaching emphasises cognitive teaching strategies through active knowledge construction in order to help students acquire scientific knowledge and understanding.

Based on the science knowledge acquisition activities in the STEM Kids module, students can surmount the difficulty of acquiring non-scientific knowledge, also known as existing knowledge (Solomon, 1993). Non-scientific knowledge is knowledge or concepts developed by students themselves through real-world experiences. In order to correct non-scientific knowledge or an alternative framework, strategies to change students' concepts are implemented so that students can restructure their concepts, such as the transmission of the process of assimilation and accommodation or the process of equilibrium proposed by Piaget (Wadsworth, 1984), to aid students' cognitive development by resolving conflicts. In order for students to restructure their concepts, the STEM Kids module also includes activities that provide cognitive conflicts that may change students' alternative concepts.

The STEM Kids module additionally enhances students' ability to apply science in real-life situations. Based on this finding, the module was effective in overcoming students' difficulties with application-level questions (MEB, 2019). In addition, it accomplished the KSSR objective of enabling students to employ knowledge and skills in a critical, creative, and analytical manner when making decisions and solving problems (MOE, 2013). This is due to the fact that one of the principles of the STEM Kids module, which is based on the learning theories of constructivism and constructionism, is to focus teaching and learning on real-world scenarios, which is to provide students with authentic learning opportunities in the context of real-world situations and practise new ideas through their common circumstances.

Conclusion

In order to achieve the goal of developing scientifically literate students, an effective PdP approach must be implemented and deployed to all students from the earliest stage of their education, regardless of their ability level. Consequently, effective learning and teaching resources or materials employing innovative teaching methods can assist in achieving this goal. Despite this, the implementation of the STEM Kids Module is not a simple task; it requires intensive training and initiatives involving educators, facilitators, and students. However, the alternative teaching and learning provided in the STEM Kids module is not impossible to implement in the formal teaching and learning of primary school and can be used as a teaching resource in the classroom, despite the study's limitations.

Recommendations

It is indicated that the research could be enhanced through further study that includes qualitative data. This is necessary to ensure that more comprehensive data mining can determine in depth the effectiveness of the interventions. Aside from that, it is suggested that, due to the limited teaching period in the classroom, additional research on the intervention be conducted outside of formal class, which can be carried out over a longer period of time.

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