STEM-STEAM IN EARLY CHILDHOOD EDUCATION IN MALAYSIA

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ABSTRACT

STEM-STEAM learning in early childhood has become a huge educational movement in recent years. It is a cross-disciplinary education approach – meant to make learning real, practical and relevant to children's daily lives. In Malaysia, STEM-STEAM learning was introduced for the first time in prekindergarten classes in 2015 through this pilot study, in order to inculcate a love for STEM learning at a young age, in hopes it will continue throughout the rest of their eduation (National Education Blueprint 2013-2025, MOE, 2013). This research[1] is a preliminary small-scale study which aims to determine the feasibility of involving 3-4 year old children in STEM-STEAM education, and the possibility of integrating it into the National ECE (PERMATA) Curriculum. In addition, this research also aims to determine the effect of STEM-STEAM education on the ability to inquire, explore, invent, and reflect, alongside the interest, communication and cooperation among children who were involved in the study.

A total of 10 STEM-STEAM projects modules were developed and validated by experts and early childhood teachers. 22 ECE teachers and 160 children from 19 ECE PERMATA centres were involved as respondents. All the 22 teachers were given a three-day intensive training course before implementing the STEM-STEAM modules at their centres. The effect of the training was gauged through pre- and post-training questionnaires, and analysed using a single group pretest-posttest design. Upon completion of the training, the teachers were asked to conduct the STEM-STEAM projects modules at their centres. The findings indicated that all the STEM-STEAM modules developed using the Project-based Inquiry Learning (PIL) approach were efficiently implemented, with 95% of the teachers having implemented between 4 to 5 modules in 5 months. The effects on the children showed a significant increase ($p<.001$) in their abilities to inquire, explore, invent, and reflect, and equally, on their interest, communication skills, and attitude towards cooperation. The effect of STEM-STEAM training towards teachers indicated a very large significant increase in terms of knowledge, skills, and self-confidence in implementing STEM-STEAM projects. The overall outcome indicates that it is feasible to implement STEM-STEAM education in ECE PERMATA curriculum, and with 3-4 year-old children in Malaysia. Several recommendations were given to the government for consideration.

[1] This paper acknowledges the contribution of co-researchers in this study: Ong Eng Tek, Md Nasir Ibrahim, Mazlini Adnan (from Sultan Idris Education University), Noriah Mohd Ishak (from Universiti Kebangsaan Malaysia), and Jameyah Shariff (from the Association of Registered Childcare Providers, Malaysia)

INTRODUCTION

STEM is not just an acronym, but a way of thinking – a philosophy of how educators at all levels should be helping students integrate knowledge across disciplines and encouraging them to think in a more connected and holistic way (Sneiderman, 2014). STEM education emphasizes on 21st Century skills acquisition which build students' proficiency in critical thinking, questioning, problem-solving, creativity and cooperation. It uses technology to connect the disciplines, and relates teaching to real-world problems. STEM education is the practical option for the IR4.0-generation and for preparing students for the future. As STEM education gained momentum in the 2000s, there was increasing demand from educationists to include the Arts as integral to the development of cognitive skills through STEM education. They argue that skills such as reading, communicating, decision-making, creativity and imagination, as well as emotional skills such as emphathy, ethics, social responsibility and cultural apreciation are needed to be ready for the job market of the future (Sousa & Pilecki, 2013; Taylor, 2016; US Bureau of Labor Statistics, 2017). The switch from STEM to STEAM education is becaming increasingly accepted as a better way to propel creativity and technological innovation and improve economic success of a nation. More importantly, it dispells the science and arts stereotypes among students, and it gives the view that everyone is able to learn and be successful in multiple academic fields.

This paper decribes the research conducted to explore the feasibility of integrating STEM-STEAM education into the existing National Early Childhood Curriculum (locally known as the PERMATA curriculum), for the 3- 4 year old children. This small scale pilot study, which was commissioned by the Prime Minister's Office, aims to assess the suitability and ability of young children to engage in a project-based inquiry learning in STEM-STEAM education, and to find out the effects of an in-service STEM-STEAM training on early childhood teachers' perception of their pedagogical knowledge, skills and attitudes. While this research originally focused on STEM education, the 'Art' component was eventually included, to suit the holistic learning needs of children at this young age. Therefore, this paper will refer to STEM-STEAM to describe the research.

LITERATURE REVIEW

Lilian G. Katz laid out that the best practice for early education is to allow children to be active, engaged, and take initiative in their own learning. She indicated that this is not only good for STEM-STEAM learning, but for overall long-term academic success (Katz, 2010). Kids, just like scientists, are eager to understand the world they live in, and are constantly exploring the world through play and experimentation. In a conference on *STEM in the Early Years*, Katz concluded: "an appropriate curriculum (STEM education) in the early years is one that encourages and motivates children to seek mastery of basic academic skills in the service of their intellectual pursuits, such as reasoning, hypothesizing, predicting, as well as the development and analysis of ideas". This powerful remark clearly illustrate the importance of integrating STEM-STEAM education into the early childhood curriculum.

Hoachlander and Yanofsky (2011) and Bybee (2013) also supported the idea that exposure of STEM-STEAM learning in early years helps develop children's critical thinking skill, reasoning, and interest towards STEM-STEAM. Because children are naturally inquistive and love to investigate, these characteristics are most appropriate for STEM-STEAM learning. Children are also described as competent learners, resilient and persistent when working on STEM-STEAM tasks. When children engage in activities that combine different elements of STEM-STEAM, they experience guided inquiry in which they must ask thoughtful questions, discover answers, apply what they learn, and problem-solve creatively (Concordia, 2017).

The importance of STEM-STEAM education in ECE is further elaborated by Chesloff in his comment made in the Education Week e-newsletter (March 25, 2013) in which he said, "There is an exciting and powerful link between STEM and early childhood…the brain is particularly receptive to learning math and logic between the ages of 1 and 4, and that early math skills are the most powerful predictors of later learning" (Chesloff, 2013).

More and more researchers support the introduction of STEM-STEAM into the early years learning experiences. Dewar (2013) indicated that when children play with Lego and blocks, they construct towers or structures that depict the work of engineers and architects. Verdine et al. (2013) similarly reported that children who frequently engaged in construction activities (for example, playing with blocks and boxes) were found to be more successful in spatial, mathematics and number skills. According to Jirout dan Newcombe (2015), children inherently possess good spatial reasoning ability, and when they build structures like towers or bridges in their block-play, they would also use their imagination and problem-solving skills in their creations. Jirout dan Newcombe (2015) observed that block-play stimulates learning in all domains of development; intellectual, physical, social-emotional and language. Many educationists agree with this view – that young children are ready to be involved in STEM-STEAM education because they are inquisitive, ask a lot of questions, love to explore their environment, embrace their imagination and creativity, and are open to invention.

To conclude this short literature review, it is correct to say that STEM-STEAM education fits well with the way young children learn, and therefore should be introduced into all ECE curricula.

Research Questions

This study aims to answer the following research questions:

1. Is it feasible to integrate STEM-STEAM into the National Early Childhood (PERMATA) Curriculum?
2. Is it feasible to implement STEM-STEAM education to 3-4 year old children in the PERMATA program?
3. What are the effects of STEM-STEAM education on the ability to inquire, explore, invent and reflect, alongside the interest, communication and cooperation among 3-4 year old children who are involved in the study?
4. What are the effects of in-service STEM-STEAM training on early childhood teachers' self-perceived pedagogical knowledge, skills and attitudes?

The term feasibility in this study is defined as “the state of something being possible or suitable”. In this study we seek to assess the practicality of integrating STEM-STEAM into the National ECE (PERMATA) Curriculum in Malaysia and the suitability of implementing STEM learning through Project-based Inquiry approach to 3-4 year old children in PERMATA centres. The outcomes of this feasibility study will be use to formulate policy recommendations to the government.

Theoretical Framework and Formulation of STEM-STEAM Instructional Strategy

The theoretical framework of this study is rooted in the Constructivist theory founded by Piaget and Vygotsky. The Constructivist theory believes that learning is a process in which the learner actively constructs or builds new ideas or concepts based on current and past knowledge or experiences, which is often determined by their social and cultural environment. The basic tenet of Constructivism is problem-solving – that as learners solve problems, they discover the consequences of their action through reflecting on past and immediate experiences, and from there, they construct their own understanding. Learning, therefore, should be active, interactive and constructive, and learners should be directly involved in hands-on real-life activities. The teacher’s role is to prompt and guide learners by asking questions that will lead children to develop their own conclusions on the subject (DeVries & Zan, 1995; Edwards, 2005; Texley & Ruud, 2017).

With the Constructivist view in the background, and the need to nurture 21st centruty skills in the children from a young age, the STEM-STEAM pedagogy was conceptualized through merging of the existing pedagogy and newly-formulated STEM-STEAM pedagogy. While the existing PERMATA curriculum uses play-based pedagogy with a ‘3E’ concept – Exploration, Experimentation and Experiencing (PERMATA Curriculum, 2013, p.34), it is however lacking in opportunites for children to Inquire (‘I’), and to Collaborate, Create and Communicate (‘3C’) which have been strongly advocated for by early childhood educators (Helm & Katz, 2001; Dockett & Fleer, 2002; Katz, 2010; Hirsh-Pasek et al., 2009; and Weisberg et al., 2015). Therefore, in the formulation of STEM-STEAM pedagogy in this research, the ‘I+3E+3C’ concept was explicitly promoted (Figure 1).

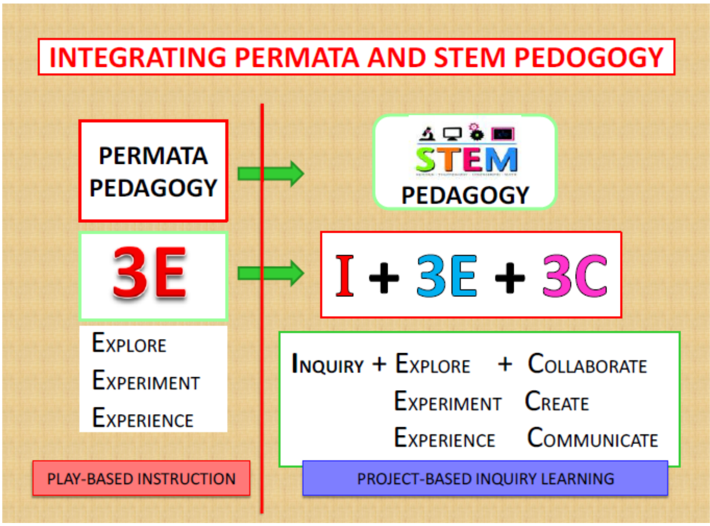

Figure1: STEM-STEAM Teaching and Learning Method

Since project-based learning has been recognized as the best approach to conduct the teaching and learning of STEM-STEAM (Bybee, 2011; Hanover Research, 2011; National Research Council of America, 2013; Banks & Barlex, 2014; Fan & Ritz, 2014), this research accordingly employed the Project-based Learning (PbL) approach with the inclusion of the 'I+3E+3C' approach. After combining these two approaches, we proposed the 'Project-based Inquiry Learning' approach (PIL) (Aminah Ayob, et al., 2015).

PIL consists of four independent phases, namely Inquiry, Exploration (including Experimentation), Invention, and Reflection. Figure 2 illustrates the enhancement from 'Play-based Learning' as the pedagogy for PERMATA curriculum, to that of Project-based Inquiry Learning pedagogy for the STEM-STEAM instruction (Aminah Ayob, 2015; Ong, et al., 2016).

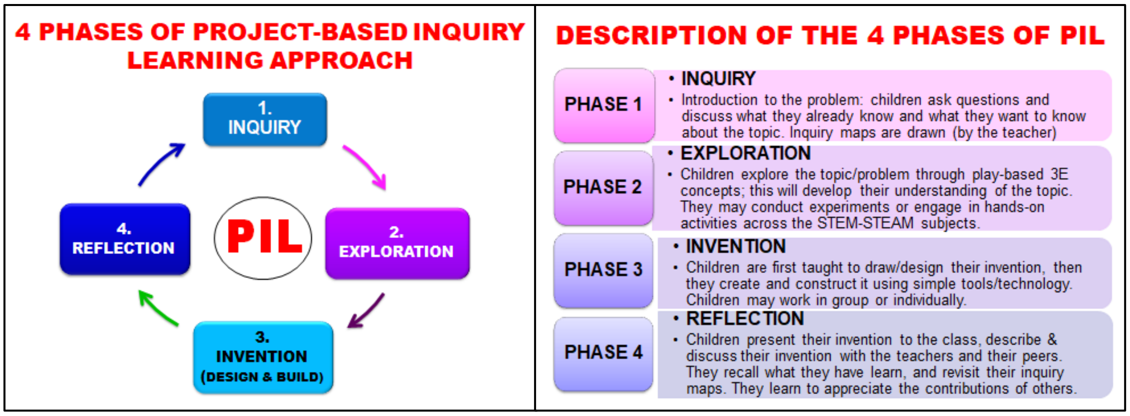

Figure 2: Description of the 4-phase Project-based Inquiry Learning Strategy

Development of STEM-STEAM modules

Detailed analysis of the PERMATA curriculum was conducted to identify concepts and learning outcomes which would be covered in the modules. This provely to be an easy task because the children were already learning about things within their environment, and the abilities and skills required to be independent in their daily lives. These, in fact, cover all aspects of a child's development, namely the physical, social-emotional, language, literacy and numeracy, science, mathematics and technology, as well as the arts and humanities. Using the concepts from the curriculum, the STEM-STEAM modules were developed.

Initially 12 modules were developed and validated, but after consultation with several practitioners and the early childhood teachers involved in this study, only 10 were selected (Table 1).

Table 1: STEM-STEAM modules for the study

Project No	Project Title	Project No	Project Title
Project 1	Rubber-band Powered Car	Project 6	Umbrella
Project 2	3R - Reduce, Reuse & Recycle	Project 7	Chicken and Eggs
Project 3	Terrarium	Project 8	My Ship
Project 4	Tie and Dye	Project 9	Paper-Making
Project 5	Composting	Project 10	Catapult

Methodology

(a) Research design

This study employed a quazi-experimental design, using 'one-group pretest-posttest' before and after treatment for both the groups of respondents, the teachers and the children (Figure 1). This design is described as most appropriate for education setting to evaluate the outcomes of an educational experiment, without any random pre-selection processes (Gay & Airasian, 2009).

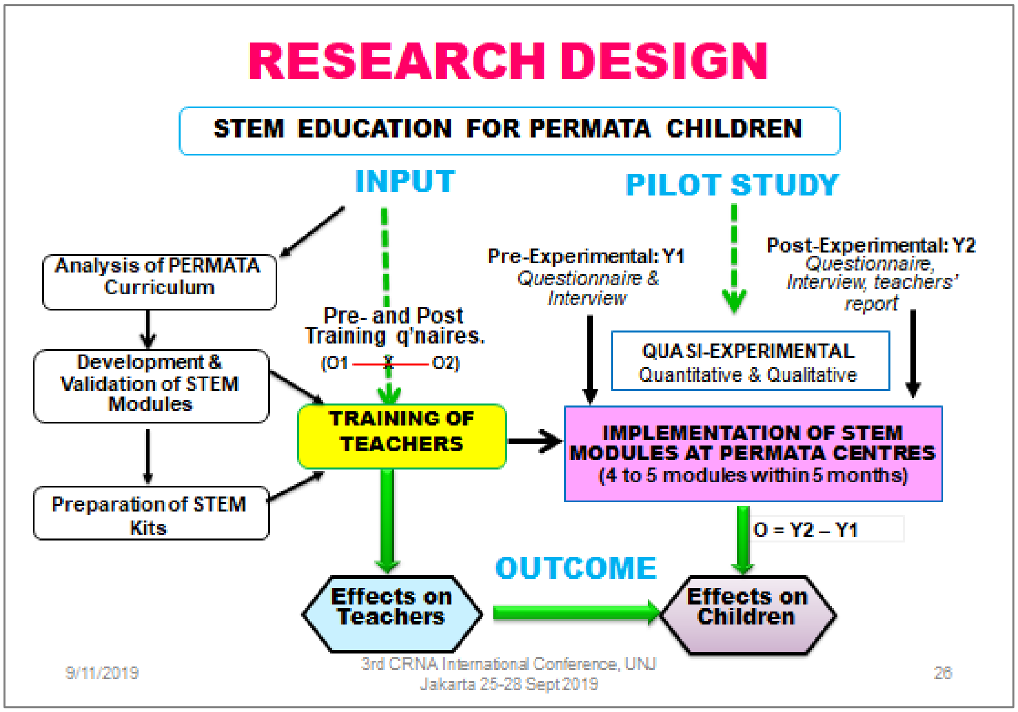

Figure 3: Quazi-Experimental Research Design

(b) Samples

A total of 22 early childhood teachers and 160 children from 19 ECE PERMATA Centres were involved in the study. The teachers were selected by officers-in-charge at the Prime Minister's Department from three states in the central zone of Malaysia, namely Selangor, Putrajaya and Perak.

(c) Instrumentation

- **Questionnire for teachers**

  Consists of 12 five-point Likert-scale items, measuring the teachers' self-rating on their knowledge, skills and attitudes with regards to the integration of STEM through Project-based Inquiry Learning approach. The same questionnaire was used before and after the training to provide a pretest and posttest data.

- **Checklist for assessing children's performance during STEM-STEAM project work**
  The checklist consists of 23 five-point Likert scale items for teachers to assess children's abilities in the four phases of the STEM-STEAM through the Project-based Inquiry Learning approach – with five items for the Inquiry phase, six items for the Exploration phase, eight items for the Invention phase, and four items for the Reflection phase. The assessment was done at every phase during the project, and for every STEM-STEAM project implemented.
- **Validity and reliablity of the questionnaire**
  The questionnaire and checklist, both are reported to have sufficient content validity as each of the items included covers every step in the STEM PIL approach. The Cronbach's alpha for the teacher's questionnaire and the checklist were determined using dataset of 22 teachers involved in the study. Cronbach alpha for the questionnaire measured at 0.898, while for the checklist was measured at 0.739, suggesting that both instruments have high and adequate internal reliablility.

(d) Parental permission (Letter of Consent)

Parental consent was obtained before the study was carried out. The teachers were asked to explain the details of how the STEM-STEAM projects would be carried out, how the children would be involved, and what the data would be collected. They were also informed that pictures of their children during the activities will be taken and used in the research report. All parents signed the consent letters.

(e) Training of teachers

The teachers followed through a three-day fully residential in-service training workshop on the integration of STEM-STEAM through PIL. In the training the teachers were familiarised with the concept of STEM and PIL, by taking on the dual role of being both teacher and child in each of the 10 projects, and walking through all the 4 phases of PIL under the facilitation of the researchers.

FINDINGS

This paper will present the findings of the third and fourth research questions first, before answering the first and second questions of this research.

(1) Effects of STEM-STEAM education (through Project-based Inquiry Learning) on the ability to inquire, explore, invent and reflect among 3-4 year old PERMATA children

Altogether there were 63 projects/modules that were implemented by teachers during the five-month period of the study. While there were 22 teachers who participated in the study, they were from 19 ECE centres, and therefore on average, each centre would have implemented between three to four projects/modules within five months.

This study has employed the quazi-experimental design, in which the STEM-STEAM modules were used as the 'treatment' on the children. However, the teachers reported they were unable to collect the pretest data because the skills required in the checklist were not established before the experiment was conducted. Nevertherless, the results of the 'posttest' was found to be enlightening.

Overall the results showed that STEM-STEAM projects/modules highly promoted the skills of invention (86.2%) and reflection (86.7%), while averagely promoted the skills of exploration (77.67%) and inquiry (61.71%) among the children involed in the study (Table 2 and Figure 4).

Table 2: Early Childhood Teachers' Perceptions on Skills Promoted in Children Through the STEM-STEAM Projects

Skills	N	Minimum	Maximum	Mean	Std. Deviation
Inquiry	63	40.00	76.00	61.7143	7.59335
Exploration	63	53.33	93.33	77.6720	7.88890
Invention	63	65.00	100.00	**85.1984**	8.03598

Reflection	63	65.00	100.00	**86.6667**	9.46130
Valid N (listwise)	63				

The mean score is lowest in the inquiry phase. This is generally true because 3-4 year old children are still lacking in ability to ask questions. This ablity need to be trained and practiced at home and in EC centres. The children seemed to be better at the invention and reflection phases. This finding tells us that children are naturaly very creative, and like to tell others of their invention.

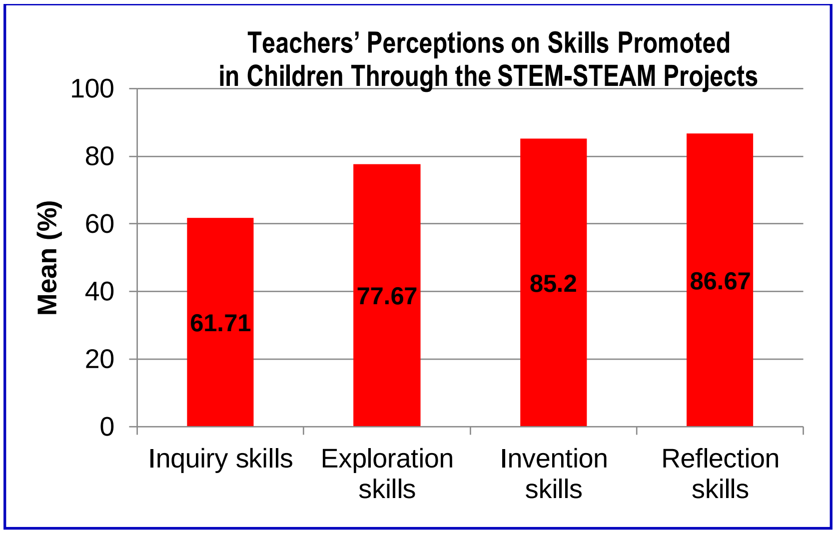

Figure 4: Teachers' Perceptions on Skills Promoted in children Through STEM-STEAM Education

(2) Effects of STEM-STEAM education on children's interest towards STEM-STEAM.

Overall, teachers reported that 84.6% of the children were very motivated/interested in carrying out the STEM-STEAM project (mean = 4.23). It is noted that the highest mean score obtained was for invention (mean=4.39). This result proved that children are naturally creative, imaginative, and love to create and invent when given the chance. Some teachers had also commented that the children had looked forward to the STEM-STEAM projects, asking repeatedly if the teacher would be continuing with the project of the day before, and once the project had been completed, they would be asking again about the next project.

Table 3: Early childhood teachers' perceptions on children's interest toward STEM-STEAM education

Code	Children's interest towards STEM-STEAM education	N	Mean	SD
M-1	Children show interest to inquire (to ask questions)	63	4.20	0.42
M-2	Children show enthusiasm to explore the topic	63	4.09	0.39
M-3	Children are ambitious to invent	63	4.39	0.47
M-4	Children are motivated to reflect	63	4.26	0.45
	Overall	63	4.23	0.36

(3) Effects of STEM-STEAM education on children's ability to communicate and cooperate

Table 4: Early childhood teachers' perceptions of children's ability to communicate and cooperate with their peers during the STEM-STEAM project

Kod	**Communication and Cooperation**	**N**	**Min**	**Std. Deviation**
C-1	Children talk and tell stories about their project	63	4.21	0.68
C-2	Children cooperate with one another during the project	63	4.17	0.58
	Overall	**63**	**4.19**	**0.51**

The results showed that children at 3-4 years of age still have an 'egocentric' character, and often find it hard to share and cooperate with others. This is understandable, and teachers should help children shed this characteristic slowly through gentle and caring support and guidance. The ability to emphatize and cooperate is very important for their future. The results showed, the skills to cooperate is slightly lower (mean=4.17) than the ability to communicate and reflect (mean=4.21) about their project in this study.

(4) Effects of in-service training on STEM-STEAM integration through Project-based Inquiry Learning (PIL) on teachers' self-perceived pedagogical knowledge, skills and attitudes

Table 5 showed the mean scores of 22 EC teachers before training (pretest) and after training (posttest). It is very encouraging to note that the teachers indicated that their 'content knowledge' had statistically significantly increased (p<.001), specifically in the knowledge and understanding of STEM-STEAM concepts (item 1 and 2), knowledge on Project-based Inquiry Learning or PIL (item 4), and the four phases in PIL (item 5). Equally, it is noted that teachers' practical knowledge (item 3, 6 and 9) had also statistically significantly increased. They also reported that their confidence levels and interest towards STEM-STEAM had increased after the training. Results for these items (10, 11 and 12) were also statistically significant.

Table 5: Results of t-test for paired samples (pre- and post- workshop) of 22 teachers.

Item No	**Item statement**	**Pre-workshop**	**Post-workshop**	**t**	**p**
1*	Knowledge of STEM-STEAM	1.91	4.18	13.893	<.001
2*	Understanding of STEM-STEAM concepts	1.73	4.18	15.588	<.001
3**	Knowing how to integrate STEM-STEAM into PERMATA curriculum	1.82	4.00	12.872	<.001
4*	Knowing why Project-based Inquiry Learning is suitable for STEM-STEAM learning	1.82	4.27	22.590	<.001
5*	Knowing all the 4 phases in Project-based Inquiry Learning in STEM-STEAM	1.77	4.32	13.917	<.001
6**	Understanding how to implement phase 1 in STEM-STEAM projects	1.68	4.32	12.969	<.001
7**	Understanding how to implement phase 2 in STEM-STEAM projects	1.68	4.14	15.588	<.001
8**	Understanding how to implement phase 3 in STEM-STEAM projects	1.68	4.27	14.229	<.001
9**	Understanding how to implement phase 4 in STEM-STEAM projects	1.73	4.14	13.230	<.001
10º	Interest towards STEM-STEAM	2.59	4.50	8.076	<.001
11#	Ability to teach STEM-STEAM to children	2.18	4.32	9.661	<.001
12#	Confident to teach STEM-STEAM to children	2.14	4.14	8.431	<.001
*	Content knowledge (4 items)				
**	Practical Knowledge (5 items)				
#	Skills (2 items)				
º	Attitudes (1 item)				

Lastly, this paper will answer the first two questions asked in this pilot research.

(5) What is the feasiblity of integrating STEM-STEAM through Project-based Inquiry Learning into the National Early Childhood (PERMATA) Curriculum in Malaysia?

The above findings clearly show that it is feasible to integrate STEM-STEAM education into the PERMATA curriculum with success. Therefore, it is recommended that the government take this pilot study seriously and start implementing STEM-STEAM education in prekindergatens and preschools, to take full advantage of the formative years during which children develop their perception and attitude towards learning and the world.

(6) What is the feasibility of implementing STEM-STEAM through Project-based Inquiry Learning to 3-4 year old children in the PERMATA program?

As with the previous question, the findings of this research prove that 3-4 year old children of PERMATA centres are capable of learning STEM-STEAM through Project-based Inquiry Learning (PIL) approach. Hence it is recommended the government take initiative to train more teachers to implement STEM-STEAM education in prekindergartens and preschools as soon as possible. It should be understood that young children are not only are capable individuals, but they are also very resilient learners – eager to learn and explore the world. Children at this age (as proven in this research) possess a rich imagination and love to create and invent. To wait until they are in primary or secondary school to implement STEM-STEAM education would be too late, and a missed opportunity.

CONCLUSION

This research was conducted to find out if it is feasible to integrate STEM-STEAM education into the ECE (PERMATA) curriculum in Malaysia, and to determine if young children aged between 3-4 years are able to learn STEM-STEAM through project-based inquiry learning approach. The research also attempted to find out the effects of STEM-STEAM learning on the children's ability to inquire, explore, invent, reflect, and communicate, as well as their interest and attitude towards cooperation (i.e., the 'I+3E+3C' abilities of the children) and the effects of the brief STEM-STEAM training on the teachers' perception of their pedagogical knowledge, skills and attitudes towards STEM-STEAM education. It was found that, overall 3-4 years old children were very capable of learning STEM-STEAM through the 4-phase project-based inquiry learning (PIL) approach, and the effects on their 'I+3E+3C' abilities were very positive. As for the training, the research found that teachers' pedagogical knowledge, skills and attitude showed statistically significant increased after the training compared to before the training. These findings, hence indicate that the integration of STEM-STEAM into EC curriculum is indeed very feasible and most appropriate if the country is to survive and thrive in a world that is constantly advancing in technological innovations in the future.

RECOMMENDATIONS

Six recommendations were made to the government form this research.

1. The government need to develop policy for integration of STEM-STEAM into national curricula.
2. Set up STEM-STEAM Committee to promote and coordinate the implementation of STEM-STEAM across the country.
3. Set up centres for STEM-STEAM training and professional development of teachers, EC operators and parents.
4. The government need to increase investment in STEM-STEAM education at all levels of schoolings.
5. The govenment need to invest in long term STEM-STEAM research so that young talents can be identified and developed early.
6. The government need to increase advocacy partnerships with major industrial players in the country to support STEM-STEAM learning in schools and preschools.

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