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The Perceptions of Pre-Service and In-Service Teachers Regarding a Project-Based STEM Approach to Teaching Science

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Abstract: Whilst much attention has focused on project-based approaches to teaching Science, Technology, Engineering and Mathematics (STEM) subjects, little has been reported on the views of South-East Asian science teachers on project-based STEM approaches. Such knowledge could provide relevant information for education training institutions on how to influence innovative teaching of STEM subjects in schools. This article reports on a study that investigated the perceptions of 25 pre-service and 21 in-service Malaysian science teachers in adopting an interdisciplinary project-based STEM approach to teaching science. The teachers undertook an eight hour workshop which exposed them to different science-based STEM projects suitable for presenting science content in the Malaysian high school science syllabus. Data on teachers' perceptions were captured through interviews, open-ended questions and classroom discussion before and at the end of the workshop. Study findings showed that STEM professional development workshops can provide insights into the support required for teachers to adopt innovative, effective, project-based STEM approaches to teaching science in their schools.

Keywords: Professional development, Project-based learning, Science, Teaching innovation, STEM

Introduction

The Malaysian educational system is currently undergoing transformation, one emphasis of which is to create a generation who can think creatively, innovatively and critically (Ministry of Education 2012a). As part of the reform efforts, the Malaysian Ministry of Education (MOE) has created initiatives that aim to increase teachers' and students' competencies in Science, Technology, Engineering and Mathematics (STEM) subjects and create learning experiences that will prepare students for the considerable array of STEM career fields.

In spite of the emphasis on STEM, science and mathematics are not subjects of first choice for a majority of Malaysian high school students, whose interest in science subjects has been steadily falling (Phang et al. 2012). During the mid-1980s, the ratio of students taking science to arts subjects was 31:69. By 2012, this had fallen to 27:78 (Ministry of Education 2012b). The number of science stream students has dropped up to 29% since 2007 (Ayob 2012). One reported reason for falling enrolment in many science programs is that students are turned off by the way these subjects are taught, as Phang et al. (2012) reported that students find studying science to be difficult, boring and not worth the effort. These findings reflect broader concerns that declining interest of students in science and mathematics may stunt the efforts to improve technological innovations to make Malaysia a high income country by 2020.

Equally alarming, recent international comparisons of 15-year-old students' performance in the 2012 Program for International Student Assessment (PISA) examination, indicate that Malaysian students scored below the international average, ranking 52 out of the 65 countries in mathematics, science and reading (OECD 2014). Further analysis shows that Malaysian students ranked 39 out of the 44 countries with a mean score of 422 on creative problem-solving, designed to assess students' abilities to apply scientific and mathematical concepts to real-world problems (OECD 2014). The mean score for all countries was 500. Malaysia had more than half the share of low achievers, revealing students' lack of the kind of skills needed to tackle real life problems that are increasingly needed in today's workplace.

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Malaysia plans to develop creative and innovative human capital to meet the nation's need in the 21st century. However, if current trends persist, the Science and Technology Human Capital Direction Plan 2020's requirement of 60% STEM workforce may not be achieved. These trends raise the question 'What can science educators do to enhance and promote interest in science and other disciplines in STEM?'
It follows that in order to attract more students into STEM careers, students should be provided with meaningful learning experiences that motivate and excite them, and that relate to their own context. To this end, science educators should be capable of offering learning experiences that engage students in realistic, thought-provoking problems, working with others, and applying their knowledge, skills and creativity in finding solutions to real-world problems. However, teachers may face significant challenges fostering an interest in STEM subjects. One of the biggest challenges for Malaysian primary and secondary science education is that few guidelines or models exist regarding how to teach using STEM approaches in the classroom. In view of these points, this study generated and examined a range of ideas on how to enhance awareness among teachers on science teaching through STEM approaches, and how these could motivate and excite students, as well as themselves, in teaching and learning science in schools.

Literature Review

STEM-project-based learning (STEM-PjBL) as pedagogy in the teaching and learning of science

Many scholars argue that for students to be fully prepared for careers in STEM, they should engage in pedagogical practices that reflect the interdisciplinary, ill-defined problems that scientists face (Anderson 2007; Clark and Ernst 2007; Marshall et al. 2007; Paige et al. 2008; Park-Rogers et al. 2007). In response, many countries have developed reforms and initiatives to shape teaching and learning across STEM disciplines. A number of these are interdisciplinary and integrative in nature, with blurred boundaries among the four disciplines (Wang et al. 2011). Linking STEM subjects offers considerable advantages, notably getting students to make sense of learning content across the four subjects, while promoting critical thinking and problem-solving skills (Beane 1997; Drake 1991; Drake 1998; Jacobs 1989; Miller 1995; Nielsen 1989).

To mirror scientists' problem-based work, a carefully crafted interdisciplinary approach to STEM teaching allows students to experience ill-defined problems, and provide them with avenues to solve these through a variety of answers, as opposed to single answer solutions more typical of didactic teaching approaches. Very little research has explicitly examined project-based learning (PjBL) as a pedagogical framework for teaching interdisciplinary STEM subjects. Actually, many of the learning experiences advocated in STEM teaching approaches are similar to the underlying principles of PjBL. Hence, PjBL in STEM (or STEM-PjBL approach) has promise as a framework for STEM initiatives.

In a STEM-PjBL learning environment, important concepts in STEM subjects can be gained in solving complex problems (Hickey 2014). Teachers in this environment could guide students in small groups to develop a variety of solutions for a given problem, encouraging collaborative learning and strengthening critical thinking and communication skills (Hickey 2014). Moreover, as students engage with the STEM-PjBL approach, they are in essence mirroring the processes used by scientists and engineers to solve real-world issues through the active construction of new knowledge and the development of problem-solving skills (Flores et al. 2002; Gutstein 2003; Rogers and Portsmore 2004).

Design-Based Science (DBS) is one example of a STEM-PjBL approach. In DBS, students actively engage with problem solving through designing and building artefacts (Fortus et al. 2005). The DBS process provides students with opportunities to carry out series of experiments, with hands-on activities that relate to STEM subjects content (Satchwell and Loepp 2002). Research has also shown that project-based learning that integrates concepts in STEM subjects has enabled students to transfer their knowledge and skills to solve real-world problems (Fortus et al. 2005), which has in many occasions led to improved scores in higher-level mathematical problem solving and scientific process skills (Satchwell and Loepp 2002).

Motivating students through a STEM-PjBL approach

Educators have shown that the use of a STEM-PjBL approach has been useful in getting students to make sense of learning science content that is within the science syllabus students study in school. This approach has particularly worked well for the academically less-inclined students. Amir (2014) argues that while the prescribed science experiments in the secondary school activity books for these students allow teachers to engage them in learning through a hands-on approach, a large number of these experiments provide little room to foster and reward these students for being able to showcase their creativity through knowledge from science. Students, in doing these experiments, are seen to be going through a routine of steps as instructed by their teachers with hardly much opportunity for them to put their imaginative and inventive skills to good use (Abrahams and Millar 2008; and Abrahams and Millar 2008). Amir and Subramaniam (2014) mentioned that these students have been observed to ask questions about the relevance of learning some of the skills and concepts taught in the experiment books. Amir and Subramaniam (2014) cited an example of their observation of students asking questions on how learning the skills in using the vernier caliper to measure the internal and external diameter of a test tube and compact disc (as described in their activity books) would be useful for them in their daily lives. The use of a STEM-PjBL could address some of these concerns in motivating students to learn science (Elkind 1999). However, the choice of the project to be presented to students does matter. Ideas from educators have shown that the use of projects that kindles interest in students does make a difference in motivating them to be interested in doing the projects (Amir 2014; Kangas 2010; Lan 2011; Meyer 2012; Resnick et al. 2000).

A way for science teachers to get students excited in learning science through projects is to infuse play into lessons. ‘Play’ is a critical issue to consider when introducing science concepts as a means to make learning science fun (Stables 1997). Play also promotes innovation and stretches students’ imagination to foster creativity (Parker-Rees 1997). Play factors can be infused into lessons that present both elementary and complex science concepts. An example of a complex physics concept that has the play factor embedded is shown by Sabin et al. (2008). In the example, the authors described how they made use of a context of superheroes belonging to different groups to present complex concepts in quantum physics. Merging elements of ‘play’ to physics, as shown through such a move, managed to generate interest in students to solve problems in physics. Another way to infuse elements of ‘play’ is through the use of toys. Using toys excites students and builds up their enthusiasm to learn science concepts (Güémez et al. 2009; Featonby 2005; Phillips et al. 2002; McGartland 1998; and Parker-Rees 1997). Toys are also not limited by a certain language and are thus suitable for use across all ages and cultures (Yau and Wong 2004). Books have been published to show how teachers can inject fun into their lessons by teaching science through the use of toys (McCullough and McCullough 2000; Sills 1999; Sarquis et al. 1995; Sarquis et al. 1997; Sumners, 1997; Taylor et al. 1995). Examples of how elements of ‘play’, such as the use of toys, have been incorporated in the crafting of teaching strategies through STEM-PjBL projects have been described in the literature. These toys can be made from low-cost everyday objects and materials (McGervey 1995). For example, Amir and Subramaniam (2009) described how students get excited about learning physics when they were guided to design and make a low cost candy floss kit gadget through the use of Aluminium foil and objects which are commonly available in the kitchen and a typical physics laboratory. Featonby (2010) and Thompson & Mathieson (2001) showed how ‘playful’ hands-on activities can generate students’ understanding in concepts related to optics through making a ‘magic mirror coin box’ toy that can be easily made using simple paper box and a plastic mirror. Oliver and Ng (1999) described how students were made to understand the concept of forces and elasticity by designing and making rubber-band driven toy aeroplanes. Subramaniam and Ning (2004) described how students were made to understand the concept of resonance by making a simple toy that is made with a wooden rod, strings and pendulum bobs. Zubrowski (2002) carried out a study with students using simple materials to make model windmills in getting them understand several science concepts related to forces and motion. Amir and Subramaniam (2006; 2007; 2014) have also described that students were able to not only able to acquire physics content through designing and making toy projects but also in being able to express their creativity through science knowledge in coming up with their own versions of toy designs.

Theoretical Framework and Purpose of Study

Since 2004, Malaysian universities have started research on project-based teaching and learning approaches in the engineering fields (Khair et al. 2011). However, STEM-PjBL approaches have yet to be developed for schools, indicating research needs about teachers’ understanding and implementation of STEM-PjBL approaches in science teaching. The literature suggests that a STEM-PjBL approach through designing and making science-based toys can be a useful pedagogy to teach science and create students’ excitement and motivation toward learning science. The researchers believe that when teachers are enabled to engage with such an approach, they would develop STEM-PjBL teaching and learning activities that could set a positive STEM culture in schools. On a bigger scale, implementing a STEM-PjBL approach in science teaching could be a catalyst towards achieving the Malaysian transformation agenda in sparking student interest in STEM subjects.

A professional development workshop approach for pre-service and in-service teachers is one way of creating teachers' awareness of science teaching through a STEM-PjBL approach (Laboy-Rush 2007). Knowledge of these teachers' views on STEM-PjBL approaches could inform innovative ways of teaching STEM subjects.
The purpose of this study therefore was to investigate the perceptions of Malaysian science teachers in adopting a STEM-PjBL approach in teaching science. A professional development workshop would provide the platform to engage science teachers in STEM-PjBL approaches to science teaching through designing and making science-based toys.
In formulating research questions, the researchers focused on:

- Examining teachers' initial perceptions of a STEM-PjBL approach in teaching science,
- Exploring their responses to the professional development experience in using the STEM-PjBL approach (namely the benefits and challenges they faced in the workshop), and
- Exploring the factors that would motivate them to implement the STEM-PjBL approach in the teaching of science in their schools.

The research questions guiding this study are:

1. How would teachers' perceptions of PjBL in STEM approach evolve as a result of their participation in this STEM-PjBL workshop?
2. What benefits are gained by teachers through engaging with the workshop?
3. What challenges do teachers face as they engage with the workshop?
4. What challenges would teachers potentially face in implementing a STEM-PjBL approach in their classrooms? What suggestions would they offer to overcome these challenges?
5. What would motivate teachers in applying a STEM-PjBL approach in teaching science in their own classes?

Methodology

Research design

A two-day professional development workshop was carried out to expose teachers to a STEM-PjBL approach in teaching science. Qualitative methods were used to address research questions and how teachers could put into practice what they learned in the workshop.

Time frame and sample

Two weekend days were allocated for workshop. The eight-hour workshop design was the same each day. On the Saturday, 25 pre-service science teachers were involved. The five male and 20 female pre-service science teachers were aged between 20 and 23, were training in Physics and Mathematics and had no teaching experience in schools. In contrast, the 21 in-service science teachers involved on day two were six males and 15 females from the Teacher Graduate Program (PPG) across Sabah. They were aged between 32 and 40 years and had between 8 and 14 years teaching experience in primary schools. Eighty-one per cent of in-service science teachers had no former experience with PjBL, whereas 19% sometimes incorporated project-based teaching approaches in their science lessons.

Collaboration with the workshop facilitator

The facilitator was a Senior Teacher from Singapore with a doctorate in science education, who has adopted a STEM-PjBL teaching approach with his science and Design & Technology (D&T) students for over nine years. Collaboration between the university and the facilitator started six months prior to the workshop. The agreed main approach was to take participants through the classroom teaching practices he adopts which mainly involves students learning science through designing and making toys. The necessary workshop materials were then made ready.

Data Collection

Research instruments included interviews (qualitative data). This approach aimed to provide a holistic view on tracking participants' perceptions of and reaction to the STEM-PjBL approach. An open-ended question "What is your overall impression of the workshop?" was stated in view of obtaining written feedback on the participants through the workshop. The instruments were reviewed by a Science lecturer and Science teacher. Since English was not the common language used by the participants, the researchers translated the instruments into Malay; these were reviewed by a Malay language teacher.

Qualitative data were gathered through (a) individual interviews (20–30 minutes), (b) workshop feedback (open questions), and (c) open discussions at the end of the workshop (60 minutes). The qualitative tools sought participants' ideas about the benefits and potential challenges they might face carrying out a STEM-PjBL approach and the likely recommendation of STEM-PjBL approach to other teachers in secondary and primary school classrooms. Structured interview protocols were employed with further probing questions following each interview question. Interviews were audio taped and transcribed.

Table 1 shows the tools that are being used to address the corresponding research questions. A group of 15 undergraduate science students were asked to comment on the readability of the items in the data capturing tools. The students agreed that all items were relevant and they should remain in the study.

Table 1. Tools being used to address the research questions

Research Question	Data Capturing Tools
1	i. Interview question administered at the end of the workshop: 'Reflecting on your own experience as a learner and as a teacher, what is your overall reaction to the approach shared in this workshop as compared to existing instructional methods?' iii. Open question: 'What is your overall impression of the workshop?'
2	i. Interview question administered at the end of the workshop: 'What particular benefits do you get while engaging in this workshop?' ii. Open question: 'What is your overall impression of the workshop?'
3	i. Interview question administered at the end of the workshop, and ii. Open discussion in class 'What particular challenges do you face while engaging in this workshop?'
4	i. Interview question administered at the end of the workshop, and ii. Open discussion in class 'In your opinion, what kind of challenges will you potentially face in implementing a STEM-PjBL approach in classroom? Please give your suggestion in order to overcome these challenges'.
5	i. Interview question administered at the end of the workshop 'Would you like to recommend other teachers to apply a STEM-PjBL approach in teaching science in their own classes? Please give your reasons why you like to do so'.

Method of Analysis

For written and verbal qualitative data, the researchers used interpretive methods (Erickson 1986) to explore common themes that emerged out of 46 participants' statements and words. An iterative process of coding, memo writing, focused coding, and integrative memo writing (Emerson et al. 1995) was followed.

Findings

The qualitative results from participants' responses are summarized in Table 4.

Table 4. Summary of participants' qualitative responses

Research Question	Participants' response	Frequency (N=46)	Percentage
1	*What were participants' reflection on STEM-PjBL approach?*		
	A fun, interesting, enjoyable and exciting approach	28	61.9
	Attract students' interest and attention	23	50.0
	Offers opportunities to be creative	15	33.6
	Positive applicability and suitability of STEM-PjBL in learning Science	12	26.1
	Increased motivation to learn	8	17.4
	Supports learning about environmental values	7	15.2
	Developing problem solving skills	3	6.5
2	*What benefits were gained by teachers through engaging with the workshop?*		
	Acquired new experience for making Science classrooms more effective	19	41.3
	Recognizing the interdisciplinary nature of STEM-PjBL approach	15	32.6
	Opening up one's mind to designing and making science-based toys	10	21.7
	Fostering creativity and thinking skills	6	13.0
	Inspired to teach in an innovative way	5	10.9
3	*What challenges did teachers face as they engage with the workshop?*		
	Insufficient time to complete tasks	20	43.5
	Lack of subject matter knowledge in a STEM-related field	12	26.1
	Unexpected conditions that contributed to unsuccessful outcomes	10	21.7
	Language as a communication barrier	7	15.2
4	*What challenges [C] would teachers potentially face in implementing a STEM-PjBL approach in their classrooms? What suggestions [S] would they offer to overcome these challenges?*		
	[C] Inadequate materials and facilities		
	Difficulty in obtaining experimental materials	44	95.7
	Rural school laboratories lack equipment provision	23	50.0
	[S] Using readily available recycled or easier accessed materials	44	95.7
	[C] A large amount of experimental materials to cope with large class	17	36.9
	[S] Conducting activities in smaller groups	17	36.9
	Students and school stakeholders take their own initiatives to obtain relevant materials.	42	91.3
	[C] Classroom time constraints	40	86.9
	[S] Carrying out STEM-PjBL lessons after school hours	40	86.9
	[C] Lack of expertise/knowledge in STEM-PjBL related projects	30	65.2
	[S] Exposing teachers to STEM-PjBL training	30	65.2
	[C] Teaching preparation for less interested students	8	17.4
	[S] Planning in advance the activities, materials and apparatus	8	17.4
	[C] Cost constraints	43	93.4
	[S] Doing group activities	23	50.0
	Getting financial support from Ministry of Education	20	43.4
5	*What would motivate teachers in applying a STEM-PjBL approach in teaching science in their own classes?*		
	Able to enhance the understanding of science content	20	43.5
	Learning by doing	14	30.4
	Exposure to real life problems	10	21.7
	Able to foster learners' multiple intelligences	10	21.7

Discussion and Conclusion

Findings from this study reveal that the professional development workshop has helped science teachers to expand their insights and build positive perceptions on the use of a STEM-PjBL approach to teach science. The teachers found that the workshop has exposed them to new teaching strategies that offer enjoyable hands-on lessons, such as getting students to design and make science-based toys, in the teaching and learning of science. The teachers believe that this approach could lead to students learning science in ways that excite them, which in turn could promote their interest, motivation and attention in learning science.

In recording the learning of science content through a STEM-PjBL approach, teachers are in favour of the idea of getting students to sketch their toy designs and provide annotations and comments alongside their sketches in describing how knowledge and skills from science contribute to their toy designs. Teachers believed that this approach would not only allow students to gain science content but also in providing an avenue for them to express their creative ideas. Furthermore, teachers felt that this approach caters to the various multiple intelligences in students' learning as described by Howard Gardner (1983), namely in tapping on the students' visual-spatial, logical-mathematics, and bodily-kinaesthetic and not just visual-linguistics modes. This could help students who may not usually motivated to learn science through the books to be more interested in learning science. Moreover, as teachers go through the STEM-PjBL approach in the workshop, they felt motivated to learn science themselves, which led to a considerable number of them indicating that they will recommend this approach to other science teachers.

There is no clear evidence in this study to measure how a teacher may improve his or her own creative teaching practices. Nevertheless, 46% of the teachers indicated that the creative learning environment setting in a STEM-PjBL approach could provide a way for science teachers to sharpen their critical and creative thinking skills. Several teachers described that the approach has inspired them to teach in an innovative way despite the limited resources. In other words, they believe that the approach will not only promote students' creativity but will also give teachers a chance to come up with creative lesson plans, such as using a toy car to teach concepts in mechanics and energy conversion, and using a Cartesian diver toy in teaching the concept of density.

The teachers were also made aware that environment values could also be developed through STEM projects. For example, in the toy solar car project, teachers themselves looked for recycled materials to make the chassis of their toy cars. Positive comments from teachers are suggestive of how their students can be taught to value the environment and promote recycling. Another aspect of the findings is that teachers value the interdisciplinary nature within STEM projects. Such responses highlight the possibility of implementing STEM-PjBL activities in schools so that students can learn across disciplinary boundaries within the STEM subjects.

Despite the many positive views of teachers on the STEM-PjBL approach in teaching science, there are however some challenges that have been raised. One challenge highlighted is the amount of time that teachers need to carry out their projects. This challenge has also been described in the works of Straw et al. (2012), Johari et al. (2013). In addressing this challenge, findings from the views of the teachers suggest that it could be possible for the STEM-PjBL lessons to be carried out after school hours to ensure that teachers have enough time to complete teaching the science syllabus, and students have enough time to complete their projects. Another challenge highlighted by teachers in this study was on the limitation of resources and cost allocated for the projects. For example, in the toy solar car project, apart from using recycled materials, for the chassis of the cars, there is also a need to purchase the motor and solar panels. This is especially obvious when a large amount of materials are needed to cope with 40 to 50 students in a class. This challenge has also been described in the works of Wang et al. (2011), Straw et al. (2012) and Weber et al. (2013). In addressing this challenge, science teachers recommended that students and other stakeholders should take their own initiative in getting the necessary material for science projects, and conducting activities are in smaller groups.

The study also highlighted that the lack of STEM training could be a challenge for a teacher adopting a STEM-PjBL in his or her lessons. The work of Honey et al. (2014) highlights that 'STEM' is an integration of disciplines, and that knowing only the science or mathematics discipline alone may not be sufficient to execute a STEM-based lesson in the classroom. In order to adopt STEM-PjBL in science teaching, a teacher needs to be well equipped with not only the content knowledge in science or mathematics, but also the instructional skills in delivering science content through a STEM-PjBL (Ferry et al. 2005, and Walker et al. 2011). Wan et al. (2013) has brought up the idea of getting more support for STEM training for Malaysian teachers. The involvement of pre-service and in-service teacher participants in this workshop highlighted that it could be possible for them to be engaged in acquiring pedagogical content knowledge in teaching science through a STEM-PjBL approach.

Because the STEM-PjBL approach offers a different approach to conventional teaching approaches (such as didactic or stepped-through science experiments), training in STEM such as the one conducted in this study has allowed teachers to realize the need to plan STEM-PjBL lessons differently (in advance) especially for students who are not interested in Science. Also, because the STEM-PjBL approach is its interdisciplinary nature, it provides opportunities for teachers to plan on how students can learn across disciplinary boundaries in Mathematics, Physics, Science, Technology, Design and Engineering. Teachers can support students to bridge the gaps between separate learning areas through a single project. The positive views of teachers in this study mirrors those reported in earlier studies (Turgut 2008; Berry et al. 2012), which highlighted that a STEM-PjBL approach would enable students to gain experience in meeting up to problems that exist in the real world which are ill-defined, and ones that require students to draw knowledge from the STEM disciplines. Their views are also similar to the ones highlighted by Weber et al. (2013), in which teachers found that STEM projects act as catalysts to help students think critically and creatively in the STEM subject areas. These attributes such as being able to see links across subjects and being able to think critically and creatively in the STEM domains could contributes to a Malaysian student's employability skills and marketability not just locally but also globally.

Implications and Recommendations

Findings from this study indicate that while considerable effort is necessary to put STEM-PjBL approaches into place, STEM-PjBL would provide practical, innovative curriculum development to support the Malaysian Educational Blueprint goals for 2013–2025. Findings from this study also revealed a number of gaps that would be needed to address in terms of training and support for teachers. This study has shown that several teachers have honestly expressed their lack of expertise in conducting STEM-PjBL approaches in their school science classes, one of the reasons being a possible reluctance to move away from conventional modes of teaching. This implies the need for educational institutions to develop more STEM-based training programs for classroom practitioners, particularly in the areas of lesson planning, instruction, STEM content, assessment techniques and fostering creative thinking skills. This could be achieved through on-going in-service STEM professional development programs. Findings also indicated that introducing five STEM-based activities at one time may overwhelm teachers. Introducing STEM-based approaches that use the latest effective teaching styles (such as the STEM-PjBL) a little bit at a time would be one way to address this challenge.

The research suggests the need to revise and re-structure the science and mathematics curriculum to produce students who are capable to think of Science, Technology, Engineering, and Mathematics in the broader terms, and not just as subjects they study in schools or just to pass examinations. There is a need to reform the Malaysian national curriculum to offer ways for students to link STEM subjects to solve real life/world problems. The STEM-PjBL approach as shown through this study can be a way to achieve this goal. Indeed, aspects of the STEM-PjBL approach could relatively easily be infused into the Malaysian national science and mathematics curriculum.

While this may be desirable, the researchers acknowledge that it is not that simple to design a multi-disciplinary project with wide coverage of STEM subjects. The researchers recommend that experts and STEM education researchers plan several multi-disciplinary projects that could present content across subjects such as Mathematics, General Science, Physics, Chemistry, Biology, Design, and Technology to students in schools. Students can then be offered one or two such projects each year, as they work towards meeting a certain curriculum requirement. This may be a practical way to prepare students to be capable of dealing with industrial-related problems when they enter the world of work.

A potential challenge that teachers raised is the amount of time needed to complete STEM projects in their science classes. The researchers found that it is important to provide sufficient time within or outside the curriculum so that the students can carry out their projects well. Also grades should be awarded for these projects based on the work and hours spent on planning and carrying them out. Credits could also be awarded for students who carry out some form of research in how content gained from their STEM projects subjects are applied in the real world.

Findings from this research also highlight an issue about infrastructure constraints. The study suggests that government should allocate sufficient budget to improve facilities and provide necessary equipment to furnish science laboratories to ensure that STEM-PjBL can be effectively achieved. Apart from the education ministry, funds could be contributed by private, STEM-related companies. Other stakeholders in education such as school staff, parents and universities could invite participation and collaboration from STEM-related companies, in view of building a future nation of STEM-trained students. This could not only develop the possibility of STEM experts and professionals to contribute to the Malaysian and global economy but could also place Malaysia's science teaching at a higher level. The researchers believe that when this happens, there would be a positive reflection in Malaysian students' performance in TIMSS and PISA results.

Finally, the study highlights a need for scholars to focus more strongly on raising teachers' awareness of the interdisciplinary nature of STEM practices and to support the integration of STEM approaches in teaching practices. The Malaysian national curriculum may need to be re-vamped to enable this. Further studies should be carried out in the near future to gain more insights on constructing suitable models for Malaysian STEM education and monitoring these. Potential further research could usefully address our understanding of the obstacles faced by teachers in implementing STEM-PjBL approaches in classrooms perceptions of students toward the STEM projects, and teachers' unbiased views of implementing STEM in their classrooms. Researchers will be required to set the standards for STEM education, produce instruments to assess the suitability of STEM-PjBL plans, and produce assessment tools in order to assess student's competency in STEM.

Study findings further suggest that involvement of the various education stakeholders, namely teachers, the ministry, STEM-related agencies, institutes of higher learning such as universities, experts and scholars will all be required and valued on the journey to produce STEM-competent students.

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References

Abrahams, A., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *Int J Sci Educ*, *30*(14),1945–1969.

Amir, N. (2014). Showcasing the creative talents in science of the academically less-inclined students through a values-driven toy story-telling project. In: Lennex LC, Nettleton KF (eds). *Cases on Instructional Technology in Gifted and Talented Education*. IGI Global Publishing, USA, pp. 141–179.

Amir, N., & Subramaniam, R. (2006). Making physics toys fosters creativity. *Phys Educ*, *41*(1),18–20.

Amir, N., & Subramaniam, R. (2007). Making a fun cartesian diver: a simple project to engage kinaesthetic learners. *Phys Educ*,*42*(5),478–480.

Amir, N, & Subramaniam, R. (2009). Making a low cost candy floss kit gets students excited about learning physics. *Phys Educ*,*44*(4),420–428.

Amir, N, & Subramaniam, R. (2012). Fostering inquiry in science among kinaesthetic learners through design & technology. In: Lennex LC, Nettleton KF (eds). *Cases on Inquiry Through Instructional Technology in Math and Science: Systemic Approaches*. IGI Global Publishing, USA, pp. 221–257.

Amir, N, & Subramaniam, R. (2014) Presenting physics content and fostering creativity in physics among less academically inclined students through a simple design-based toy project. In: de Silva E (ed). *Cases on Research-Based Teaching Methods in Science Education.* IGI Global Publishing, USA, pp. 157–196.

Anderson, J. (2007). Enriching the teaching of biology with mathematical concepts. *Am Biol Teach, 69*(4), 205–209.

Ayob, A. (2012). *Cara Meningkatkan Minat Pelajar terhadap Sains dan Matematik* [*Ways to Increase Student Interest in Science and Mathematics*], Paper presented in Colloquium on Mathematics and Science Education, Universiti Malaya.

Beane, J.A. (1997). *Curriculum Integration: Designing the Core of Democratic Education*. New York: Teachers College Press.

Berry. M.R., Chalmers, C., & Chandra, V. (2012). STEM futures and practice, can we teach STEM in a more meaningful and integrated way? In: Yu SQ (ed). *2nd International STEM in Education Conference*, 24–27 November, 2012. Beijing, China.

Clark, A.C., & Ernst, J.V. (2007). A model for the integration of science, technology, engineering, and mathematics. *Technol Teach*, *66*(4), 24–26.

Cook, K.L., & Buck, G.A. (2013). Pre-service teachers' understanding of the nature of science through socio-scientific inquiry. *Electron J Sci Educ*, *17*(1),1–24.

Drake, S.M. (1991). How our team dissolved the boundaries? *Educ Leadersh*, *49*(2),20–22.

Drake, S.M. (1998). C*reating Integrated Curriculum: Proven Ways to Increase Student Learning*. Corwin, Thousand Oaks, CA.

Elkind, D. (1999). *Dialogue on Early Childhood Science, Mathematics, and Technology Education*. Medford: American Association for the Advancement of Science.

Emerson, R., Fretz, R., & Shaw, L. (1995). *Writing Ethnographic Field-Notes*. Chicago IL: University of Chicago Press.

Erickson, F. (1986). Qualitative methods in research on teaching. In: Wittrock MC (ed) *Handbook of Research on Teaching* (3rd eds.). New York: Macmillan, pp. 119–161.

Featonby, D. (2005). Toys and physics. *Phys Educ*, *40*(6),537–543.

Featonby, D. (2010). Magic physics? *Phys Educ*, *45*(1), 24–31.

Ferry, B., Kervin, L., Cambourne, B., Turbill, J., Hedberg, J., & Jonassen, D. (2005). Incorporating real experience into the development of a classroom-based simulation. *J Learn Des*, *1*(1), 22–32.

Flores, A., Knaupp, J., Middleton, J.A., & Staley, F.A. (2002). Integration of technology, science, and mathematics in the middle grades: a teacher preparation program. *Contemp Issues Tech Teach Educ, 2*(1),31–39.

Fortus D, Krajcik, J., Dershimer, R.C., Marx, R.W., & Mamlok-Naaman, R. (2005). Design-based science and real-world problem solving. *Int J Sci Educ*, *27*(7), 855–879.

Foundation, N.S. (2010). *Diversifying the STEM pipeline the model replication institutions program.* Washington DC: Institute for Higher Education Policy.

Gardner, H. (1983). *Frames of Mind: The Theory of Multiple Intelligences*. New York: Basic Books.

Güémez, J, Fiolhais, C., & Fiolhais, M. (2009). Toys in physics lectures and demonstrations - a brief review. *Phys Educ*, *44*(1), 53–64.

Gutstein, E. (2003). Teaching and learning mathematics for social justice in an urban, Latino school. *J Res Math Educ*, *34*(2),37–73.

Hickey, R. (2014). Project-based learning: where to start? *Techniques: Connecting Education & Careers*. *89*(2), 8–9.

Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research. Committee on Integrated STEM Education: National Research Council, Retrieved from http://www.nap.edu/catalog.php?record_id=18612

Ingram, E.L., & Nelson, C.E. (2006). Relationship between achievement and students' acceptance of evolution or creation in an upper-level evolution course. *J Res Sci Teach*, *43*(1), 7–24.

Jacobs, H.H. (1989). *Interdisciplinary Curriculum: Design and Implementation*. Alexandria VA: Association for Supervision and Curriculum Development.

Johari, S., Nor Hasniza, I., & Mahani, M. (2013). Implementation of problem based learning in higher education institutions and its impact on students' learning. In: Khairiyah M-Y., Mahyuddin, A., Mohamad Termizi, B., Graaff, E., Kolmos, A., & Fatin Aliah, P., *PBL Across Learning* (eds). Paper presented at Fourth International Research Symposium on PBL 2013, Universiti Teknologi Malaysia, 2–3 July 2013. Aalborg University Press, Denmark, pp. 66–73.

Kangas, M. (2010). Creative and playful learning: learning through game co-creation and games in a playful learning environment. *Think Skills Creativy*, *5*(1), 1–15.

Khair, N., Ahmad Nabil, Md. N., Dayana Farzeeha, A., Mohd Safarin, N. (2011). Problem based Learning (PBL) and Project-based Learning (PjBL) in Engineering Education: A comparison, *Proceedings of the IETEC' 11 Conference*, Kuala Lumpur, Malaysia

Laboy-Rush, D. (2007). *Integrated STEM education through project based learning*. Retrieved from http://www.rondout.k12.ny.us/UserFiles/Servers/Server_719363/File/12-13/STEM/STEM-White-Paper%20101207%20final[1].pdf.

Lan, B.L. (2011). Design Projects in First-Year Physics for Engineering, *Proceedings of the IETEC'11 Conference*, Kuala Lumpur, Malaysia., Retrieved from http://www.ietec-conference.com/ietec11/Conference% 20Proceedings/ ietec/papers/Conference%20Papers%20Refereed/Wendesday/WP3/WP3.1_39.pdf.

Marshall, J., Horton, B., & Austin-Wade, J. (2007). Giving meaning to the numbers. *Sci Teach*, *74*,36–41.

McCullough, J., & McCullough, R. (2000). *The Role of Toys in Teaching Physics*. College Park, MD: American Association of Physics Teachers.

McGartland, G. (1998). Using toys to foster creativity and innovation at work. *Innov Lead*, *7*(3), 330. Retrieved from http://www.winstonbrill.com/bril001/html/article_index/articles/301-350/article330_body.html.

McGervey, J.D. (1995). Hands-on physics for less than a dollar per hand. *Phys Teach*, *33*(4), 238–241.

Meyer, D. (2012). Designing design challenges - getting the details right: using engineering problems to enact inquiry learning. *Sci Teach*, *79*(2), 58–62.

Miller, K.A. (1995). *Curriculum: To Integrate or not to Integrate*. Ohio, USA: Youngstown State University.

Ministry of Education. (2012a). M*alaysia Education Blueprint 2013–2025: A Preliminary Report.* Putrajaya: MOE.

Ministry of Education. (2012b). *Laporan Strategi Mencapai Dasar 60:40 Aliran Sains/Teknikal: Sastera,* [*Strategies to Achieve 60:40 Science/Technical:Arts Stream Policy Report*]. Putrajaya: MOE.

Mujtaba, T., & Reiss, M. (2014). A survey of psychological, motivational, family and perceptions of physics education that explain 15-year-old students' aspirations to study physics in post-compulsory English schools. *Int J Sci Math Educ*, *12*(2),371–393.

Ng, Y.K., Mak, S.Y., & Chung, C.M. (2002). Demonstration of Newton's third law using a balloon helicopter. *Phys Teach*, *40*, 181–182.

Nielsen, M.E. (1989). Integrative learning for young children: a thematic approach. *Educ Horiz*, *68*(1),18–24.

OECD. (2014). *PISA 2012 Results in Focus*. Retrieved from http://www.oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf.

Oliver, D., & Ng, T. (1999). Rubber-band-driven airplane contest. *Phys Teach*, *37*(2),108.

Paige, K., Lloyd, D., & Chartres, M. (2008). Moving towards transdisciplinarity: an ecological sustainable focus for science and mathematics pre-service education in the primary/middle years. *Asia Pac J Teach Educ*, *36*(1),19–33.

Parker-Rees, R. (1997). International Conference on Design and Technology Educational Research and Curriculum Development, Loughborough University of Technology., pp 20–25, Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/1458/3/parkerrees97.pdf.

Park-Rogers, M., Volkmann, M., & Abell, S. (2007). Science and mathematics: a natural connection. *Sci Child*, *45*(2),60–61.

Phang, F.A., Abu, M.S., Ali, M.B., & Salleh, S. (2012). *Faktor Penyumbang Kepada Kemerosotan Penyertaan Pelajar Dalam Aliran Sains: Satu Analisis Sorotan Tesis* [*Contributing factors to the decline in student participation in Science Stream: A Thesis Highlights Analysis*]. Skudai: Universiti Teknologi Malaysia.

Phillips, A.P., Palazolo, P.J., Magun, J.S., Camp, C.V., & Schmucker, D. (2002). Powerful Play: Using Toys as Tools in Engineering Education. *Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition*, American Society for Engineering Education., Retrieved from http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F26%2FAC%25202002Paper1050.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=.

Resnick M, Berg R, & Eisenberg M (2000) Beyond black boxes: bringing transparency and aesthetics back to scientific investigation. *J Learn Sci*, *9*(1),7–30.

Rogers C, & Portsmore M (2004) Bringing engineering to elementary school. *J STEM Educ,* 5(3),17–28.

Sabin, J.R., Trujillo, R.C., Öhrn, Y., & Deumens, E. (2008). Theoretical investigation of fragmentation effects in the energy deposition of swift ions in formaldehyde. J. Phys.: Conf. Ser. 101 012009. doi:10.1088/1742-6596/101/1/012009.

Sarquis, J., Sarquis, M, & Williams, J.P. (1995). *Teaching chemistry with TOYS: activities for grades K-9.* USA: McGraw-Hill, Learning Triangle Press.

Sarquis, J., Hogue, L., Sarquis, M., & Woodward, L. (1997). *Investigating Solids Liquids and Gases with Toys*. Middletown: McGraw-Hill, Miami University.

Satchwell, R.E., & Loepp, F.L. (2002). Designing and implementing an integrated mathematics, science and technology curriculum for the middle school. *J Ind Teach Educ*, *39*(3).

Sills, T.W. (1999). *Science fun with Toys*. Chicago: Dearborn Resources.

Stables, K. (1997). Critical issues to consider when introducing technology education into the curriculum of young learners. *J Technol Educ*, *8*(2),50–65.

Straw, S., MacLeod, S., & Hart, R. (2012). Evaluation of the Wellcome Trust Camden STEM initiative. Slough: NFER.

Subramaniam, R., & Ning, H.T. (2004). Pendulums swing into resonance. *Phys Educ*, *39*(5), 395.

Sumners, C. (1997). *Toys in space: exploring science with the astronauts*. Blue Ridge Summit, PA: McGraw-Hill.

Taylor, B.A.P., Poth, J., & Portman, D.J. (1995). *Teaching physics with toys: activities for grades K-9*. Middletown: OH Terrific Science Press.

Teo, T. (2008). Pre-service teachers' attitudes towards computer use: a Singapore survey. *Australas J Educ Technol*, *24*(4),413–424.

Thompson, G., & Mathieson, D. (2001). The mirror box. *Phys Teach*, *39*(8),508–509.

Turgut, H. (2008). Prospective science teachers' conceptualizations about project based learning. *Int J Instruct, 1*(1),61–79.

Walker A, Recker, M., Robertshaw, M.B., Olsen, J., Leary, H., Ye, L., & Sellers, L. (2011). Integrating technology and problem-based learning: A mixed methods study of two teacher professional development designs. *Interdiscip J Prob Based Learn*, *5*(2),70–94.

Wan, A., Wan, A., Roslina, S., Ruhizan Mohammad, Y., Saemah, R., Khairiyah Mohd, Y., Nor Kamariah, N., & Mohd Saleh, J. (2013). An exploratory study on the implementation of POPBL among lecturers of higher education institutions in Malaysia. In: Khairiyah M-Y, Mahyuddin A, Mohamad Termizi B, Graaff E, Kolmos A, & Fatin Aliah P, *PBL Across Learning* (eds) Paper presented at Fourth International Research Symposium on PBL 2013, UniversitiTeknologi Malaysia, 2–3 July 2013. Aalborg University Press, Denmark, pp 61–65.

Wang, H.H.,Moore,T.J, Roehrig, G.H., & Park, M.S. (2011). STEM integration: teacherperceptions and practice. *Journal of Pre-College Engineering Education Research*, *1*(2),1–13.

Weber, E., Fox, S., Levings, S.B., & Bouwma-Gearhart, J. (2013). Teachers' conceptualizations of integrated STEM. *Acad Exchange*, *17*(3),47–53.

Yau, C.M., & Wong, V.P. (2004). Using Toys To Teach Science, *Proceedings of the Educational Research*

Zubrowski, B. (2002). Integrating science into design technology projects: using a standard model in the design process. *J Technol Educ*, *13*(2), 48–67.

Zwiep, S.G., & Benken, B.M. (2013). Exploring teacher's knowledge and perceptions across mathematics and science through content rich learning experiences in a professional development setting. *Int J Sci Math Educ*, *11*(2), 299–324.

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