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The 4<sup>th</sup> Consortium Asia-Pacific Education Universities (CAPEU) 2017 is one of a series of international conferences held by Universitas Negeri Surabaya (Unesa), Indonesia, in collaboration with some universities in Asia, South East Asia, and Pacific as well as with other institutions. Unesa held this event as its commitment to research activities and collaborations to strengthen the academic climate in Asia and beyond. This event is a perfect platform for senior and junior researchers in the fields of sciences, technology, engineering, and mathematics to exchange experiences and ideas and to build a network. In addition, this conference will certainly help improve scientific publication of researchers and lecturers.

The theme of this year event is “Innovations for Human Talents”. This two-day conference aims to bring together educators, graduate students, researchers, and faculty members of the CAPEU and of other countries to contribute to the concept of the STEM in education and to formulate goals on how this can be applied and implemented in their respective countries. The researchers can do their bit with their research findings in promoting better achievement of research innovation for the betterment of human life.

This conference has attracted much attention from scientific communities from diverse background of research interests. There are 130 research-based papers submitted and presented at the conference. Out of the submitted papers, the selected ones, around 56 papers, will be published by IOP Publishing. The papers have a wide range of topics, namely education, teaching and learning, assessment, community engagement, job opportunities related to STEM, and parents’ involvement in enhancing STEM. The topics are not limited to, but mostly of the above-mentioned areas of interest.

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## Integrating STEM education through Project-Based Inquiry Learning (PIL) in topic space among year one pupils

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# Integrating STEM education through Project-Based Inquiry Learning (PIL) in topic space among year one pupils

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**Abstract.** This research aims to investigate the effect of integrating STEM education through Project-based Inquiry Learning (PIL) and the users of the STEM modules which consists of five projects on topic Space in Year One Mathematics Syllabus in *Kurikulum Standard Sekolah Rendah* (KSSR) of Malaysia. STEM education in primary school focuses on the introduces and awareness of students about the importance of STEM education. The projects in STEM modules are covering the different ethnic cultures in Malaysia. The modules are designed using the four phases in PIL. Concepts and the explanation of STEM education on each project are emphasized and provided in the modules so the teachers able to carry out the projects by using the modules. By using the modules in primary Mathematics, the students and teachers will be more understanding on how to integrate the Mathematics' concepts in STEM education.

## 1. Introduction

To enhance the quality of education in Malaysia, the Ministry of Education (MOE) has developed and launched the Malaysia Education Blueprint 2013-2025 (PPPM) which aims to transform the education system in Malaysia in order to compete with the growing international education system. To achieve this objective, the MOE has identified 11 shifts that can result in changes in the education system in Malaysia. The first shift in this blueprint has stated: Provide Equal Access to Quality Education of an International Standard. One of the benchmarks in the first shift is to strengthen the quality of Science, Technology, Engineering, and Mathematics (STEM) education.

In order to produce the educated citizens and meet the needs of 21st-century skills, STEM education is an important interdisciplinary subject which fulfilled the needs. Each individual must know and understand the basic concepts of the STEM. STEM education has given the best opportunities for students to understand the world in a holistic manner. According to Hays Blaine Lantz, Jr. (2009), STEM education offers students one of the best opportunity to make sense of the world holistically, rather than in bits and pieces. STEM education removes the traditional barriers erected between the four disciplines, by integrating them into one cohesive teaching and learning paradigm [1].

To equip the students with the skills needed to face the challenges of a changing global with the application of STEM, the MOE is responsible for ensuring an increase in the ratio of students who wish to pursue scientific and technical fields. In the PPPM 2013-2025, the MOE has stated the five factors that cause the decline and the quality of student outcomes in STEM education,



- Lack of awareness in STEM education.
- STEM subjects considered difficult.
- A solid curriculum content.
- Less consistent with the quality of teaching and learning.
- Old and inadequate infrastructure.

These factors or problems must be overcome so that the desire of MOE in PPPM 2013-2025 can be achieved. In 2014, Dr. Suhaidah Tahir, Dominador D. Mangao and Dr. Nur Jahan Ahmad of the Southeast Asian Ministers of Education Organization Regional Center for Education in Science and Mathematics (SEAMEO RECSAM) have designed a conceptual framework for the development of STEM education in Malaysia. In this framework, it divided the development of STEM education into six phases, which is from early childhood to industry or community. In this paper, we focused on the second phase which is on the primary or elementary school, the focus is helping the students to make the connection or build the foundation in STEM education [2].

In the primary or elementary school, the STEM education focuses on the introduction and gives the awareness to students about the importance of STEM education. In other words, it gives a draft idea of the integration of the four fields in STEM education. Initial step to introduce STEM education is to provide the standards-based learning which based on the problem-solving and inquiry-learning method in real situations to link up the four subjects in STEM education. In other words, the goal of STEM education is designed based in the inquiry-learning by used the thinking skills in science and technology to solve the everyday real life problems.

The purpose of this research is to enhance the integration of STEM education in Mathematics *Kurikulum Standard Sekolah Rendah* (KSSR) through an inquiry-based approach which the activities focus on project-based learning or using the Inquiry-Based Learning Project (PIP).

## **2. Project-based Inquiry Learning (PIL)**

Inquiry-Based Learning Project (PIP) is the method that emphasizes on the sciences skills and attitude, high order thinking skills, creative problem solving, design and construction of the object-based technology and encourages the children to communicate and work in teams [3]. There are four phases in PIP, namely Inquiry, Exploration, Experimentation, and Reflection.

In the Inquiry Phase, students ask questions about what they want to know and with the guidance of teachers, the students may decide the issues or topics they want to be investigated.

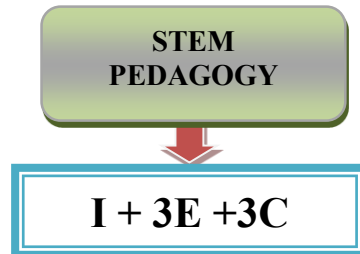
In the Exploration phase, students are looking the information about issues or topics that have been identified. Search information by using various methods, such as the internet, video, nature walk, visit, study science books, and so on. The students develop the new knowledge and strengthen the existing knowledge on the subject they studied or had been exploring. After receiving all the necessary information, the students will determine the suitable materials for the projects.

In the Experimentation phase, students build or develop their inventions or ideas by creating the model according to what they had planned in the Exploration phase. Students demonstrate the product and answer questions that they ask in the first phase.

In the Reflection phase, students reflect on the learning process which they had gone through and give a view of the product or invention that they have produced. In this phase, students also will be asked to give the opinion on the interest, awareness, appreciation and what they want to do next.

These four phases in PIP are adapted and modified from the implementation of STEM education in the PERMATA curriculum. The aim of modified PIP is hoped that it can be implemented into the Malaysia's primary school curriculum [4].

PIP is the method should use in teaching STEM education which can be represented in Figure 1. The inquiry is the initial phase to stimulate the curiosity of students. 3E in the PIP is Exploring, Experiment and Experience and 3C in the PIP are Collaborate, Create and Communicate.



**Figure 1.** Inquiry-Based Learning Project (PIP) method

### 3. STEM modules

In Malaysia, the development of STEM education is an important agenda for the transformation of the education system and prepares the students to meet the challenges of the 21st century. To help the teacher to enhance the knowledge and development of STEM education, in this research a STEM modules using the PIP method based on the ADDIE Module has designed.

STEM modules in this research have been characterized by using variety traditional culture of Malaysia. Projects in the STEM modules chose the traditional culture in Malaysia because Malaysia is a country made up from different races and ethnic such as Malay, Chinese, Indian and other which practices different and unique traditional culture. In the modules, students not only understand the STEM concepts involved, at the same time the students also can understand the tradition of different races in Malaysia.

In these modules, five projects that use PIP methods have been designed. The skills in these five projects are integrating the knowledge of science, technology, engineering, and mathematics while producing products. These five projects have been a focus on the topic of space in Revised KSSR Year 1 Mathematics Syllabus. These five projects are:

**Table 1.** Five STEM Modules

No	Project	STEM Concept Involved
1	Tangling	Shape and size of the Tanglung, a number of materials that needed such as color paper, burning, light, and design of Tanglung.
2	Tudung Saji	Measure and counting, shape and size, the usage and design of the Tudung Saji.
3	Kolam	Measure, shape, size, symmetry and how to stick the rice or sands on the paper and the design of Kolam.
4	Wau	Measure, shape, size, symmetry and how to let the Wau fly in the sky.
5	Chinese Yoyo	Measure, shape, size, symmetry and how to balance the Chinese Yoyo while playing.

### 4. Research methodology

The respondents in this research are a focus on the year one student in the ordinary schools under the Ministry of Education of Malaysia. Two classes of the year, one students were chosen as the population for the study. One class of the student as the treatment group while another class as control class. To get effectiveness on integrating STEM education in Mathematics, this research used a quasi-experimental design for the study group and used the existing year one class. This research will be conducted in six weeks and depend on the progress of the students[5].

In this research, four instruments were built to evaluate the effectiveness of implementing the PIP method based on STEM modules. These instruments are intended to support the validity and reliability of the PIP. These instruments are pre-test and post-test, questionnaires, interviews and the project implementation monitoring report to support the outcome of the research. This study aimed to identify the reliability integration of the STEM education in the field of Mathematics, results of pre-tests and

post-tests, questionnaires and interview can only give a rough idea about the integration of STEM education.

Questionnaires to evaluate the understanding, interest, and attitude towards the STEM education was distributed to the treatment group's students. The Cronbach's alpha test was conducted to determine the internal consistency. This method assumes that each item is considered to be a similar test and all correlations between the measured items are the same. The result of the questionnaires shown that confidence coefficient Cronbach's alpha value is 0.76, so the reliability for this questionnaires is accepted.

Reliability Statistics		
Cronbach's Alpha Based on		
Cronbach's Alpha	Standardized Items	N of Items
.756	.775	30

**Figure 2.** Reliability statistics

## 5. Pilot Study

A pilot study had been done using the project five in the STEM modules, make a Chinese Yoyo. The project had carried out in two places, for example, the *Expo Mampan* in RTC Gopeng, Perak and the *Majlis Professor Negara* at FELDA UMAS, Tawau, Sabah. During the activity, teacher or the facilitator guides the students on how to make a Chinese Yoyo. The teacher or the facilitator used the instructions in module five to carry the project. While the students are making the Chinese Yoyo, the facilitator asked the students questions about the shape, the size and how to make a yo-yo balance while playing. The questions asked by facilitator as below

- What is the shape of Chinese Yoyo?
- What is the design of Chinese Yoyo to make it spin?
- How to make a Chinese Yoyo?

These questions are asked in the Inquiry Phase, the purpose asked these questions is to cause the curiosity among the students. From the curiosity, the students are interested to find out more about the Chinese Yoyo. In the same time, the facilitators guide the students followed the four phases in Project-based Inquiry Learning (PIL) and let the students understand the integrated STEM knowledge in this project. The Chinese Yoyo in STEM modules can consider special and interesting because the materials that used in this project are recycled materials, such as mineral water bottles, chopstick, screw, and nylon string to make this project.

From the responses and feedback from the students, noticed that the students are enjoying themselves while making the Chinese Yoyo, they also feel excited because the used the recycled bottles to make a Chinese Yoyo. The Chinese Yoyo in this project not only because it is a Chinese traditional game but it also consists of STEM knowledge, such as how to make a balance Yoyo, how to keep its balancing while played the Chinese Yoyo and what is the design can use for Chinese Yoyo.



3.1. Students make the Chinese Yoyo



3.2. Facilitator gives instructions



3.3. Students play the Chinese Yoyo



3.4. Students play the Chinese Yoyo

**Figure 3.** Pilot Study at *Expo Mampan* in RTC Gopeng, Perak

This two pilot study was facilitated by main author and co-author. The project made by students has followed the four phases of PIL in the STEM modules. There was no boredom among the students, from the participated of students, they had employed the hands-on and minds-on while making the Chinese Yoyo.



4.1 Students sit in a group



4.2 Students sit in a group



4.3 Facilitator gives instructions



4.4 Facilitator gives instructions

**Figure 4.** Pilot Study at *Majlis Professor Negara* at FELDA UMAS, Tawau, Sabah

## 6. Conclusion and Discussion

The purposes of this study are to improve the integration of STEM education in Mathematics through PIP. The stem is a teaching and learning approach that involves the application of knowledge, skills, and values of STEM to solve the real-life problem in the context of daily life, society, and the environment. This approach encourages students to ask questions and explore the environment through inquiry and solve the issues related to the real world situation to cultivate the practice of STEM. By using the STEM modules based on the PIP, the teacher will be more confident and able to carry out the STEM education in school. To achieve the goals of PPPM 2013-2015 of MOE, the teacher themselves must change their mind and accept the challenges of the teaching and learning in this new era, so they can produce the students fulfilled the need of 21<sup>st</sup> century [6].

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## Mathematics Pedagogical Standards: A Suggested Model of Instruction in Enhancing the Mathematics Teacher's Quality of Instruction

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# Mathematics Pedagogical Standards: A Suggested Model of Instruction in Enhancing the Mathematics Teacher's Quality of Instruction

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**Abstract.** The paper aims at identifying the standards for teaching and learning of mathematics based on National Council of Teacher of Mathematics (NCTM, 2000), The Australian Association of Mathematics Teachers (AAMT, 2006) and Training and Development Agency for School (TDA, 2007). These known standards were used as a guide in identifying the constructs of the mathematics teacher's instruction in the classroom. The survey method used in which a questionnaire instrument encompassed on the four identified constructs on the standards for teaching and learning of mathematics, namely *professional practices*, *professional attributes*, *professional knowledge*, and *professional instructional processes*. The instrument was tested during a pilot study and a Cronbach's Alpha reliability index of greater than 0.85 was obtained. The actual research was carried out in Peninsular Malaysia involving 224 secondary schools with 1.120 mathematics teachers and 108 primary schools with 540 mathematics teachers. From the selected schools, only 820 secondary mathematics teachers (73.2%) and 361 primary teachers (66.9%) gave a response to the mailed questionnaires. The findings of the study revealed that the secondary and primary mathematics teachers strongly agreed on three constructs; *professional practices*, *professional attributes* and *professional instructional processes*.

## 1. Introduction

Shulman highlighted the notion that, '*teaching necessarily begins with a teacher's understanding of what is to be learned and how it is to be taught*' [1]. As such, decisions made by the teacher before, during and after the instruction are crucial not only to the teacher but to the learners as well in enhancing the quality of the instruction. The decisions made must be based on a credible professional guidance. Hence, to help the teachers, NCTM [2], introduced '*The Professional Standards for Teaching Mathematics*'. The standards proposed by NCTM were to guide American mathematics teachers on how the teaching and learning of mathematics should be practiced in the classrooms. NCTM also described two types of standard namely the content standard for teaching specific mathematical topics and the process standard that involves pedagogy and the methods of instruction. This emphasized through the statement, '*Teachers*



*need to know and use mathematics for teaching that combines mathematical knowledge and pedagogical knowledge* [2]. In the *Teaching Principle* NCTM [2] put forward three main aspects of effective instruction. These aspects are the needs of a sound knowledge and understanding of mathematics, the students as learners and sound pedagogical strategies.

The standards for teaching mathematics also introduced in Australia for teachers to practice and this known as the *Standard for Excellent in Teaching Mathematics in Australian School* [3]. The proposed standards would serve as a guide for mathematics teachers about the quality required to be an effective mathematics teacher, ways to implement his or her roles and responsibilities competently and creating his or her own teaching philosophy.

The situation in Malaysia is a bit different. Here, the various divisions in the Ministry of Education have the responsibilities towards the development of education. In addition to producing quality teachers, the Ministry also wishes that these quality teachers remain within the orbit of the national education system and sustain their quality until they retire from the educational service [4]. To achieve these aims the Ministry introduced the *Malaysian Standards for A Quality Education* [5] to evaluate the quality of teaching in the classroom and *Malaysian Standards for Teachers* [6] to enhance the quality and knowledge of pre-service teachers. These two standards are apparently different from the perspective of their respective aims. This paper discusses the constructs that have been identified as the bases for teaching mathematics and that have been evaluated by using the *Structure Equation Modelling (SEM)*. SEM is used to determine the constructs that contributed greatly to enhancing the quality of teaching and learning of mathematics and hence forming a standard mathematics pedagogical model that can be practiced to achieve an effective mathematics instruction.

## 2. Methods

Four constructs or components of the pedagogical standards for teaching mathematics were identified and they were *Professional Knowledge*, *Professional Practices*, *Professional Instructional Processes* and *Professional Attributes*. Overall, 17 elements were identified from the literature review as in Table 1. The items for the questionnaire were constructed based on the four components or construct to gain a degree of approval from the respondents using a five-point Likert scale. Each item was then analyzed based on the frequencies and percentages of the degree approval towards the pedagogical standards for teaching mathematics. This was followed by the analysis of the average for each component of the standards. The degree of perception and the mathematics teachers' knowledge category were measured using the scales as proposed by Nugent, Sieppert dan Hudson [7] as in Table 2. In addition, Cronbach's Alpha Reliability Index of the instrument was determined during the pilot study with an index of 0.85 [8] and 0.95 [9].

**Table 1.** Mathematics Pedagogical Standards components

<b>Element</b>	<b>Component</b>
<b>PA</b>	<b>Professional Attributes</b>
SA	Self Attribute
PD	Professional Development
RSC	Responsibility for School & Community
<b>PP</b>	<b>Professional Practices</b>
PMI	Planning of Mathematics Instruction
PIMI	Pedagogical Implementation of the Mathematics Instruction
ME	Monitoring & Evaluation

Element	Component
<b>PK</b>	<b>Professional Knowledge</b>
MCK	Mathematics Content Knowledge
KICTAMI	Knowledge of ICT Application in Mathematics Instruction
KIQ	Knowledge of Intellectual Quality
KL	Knowledge of Learners
KMC	Knowledge of Mathematics Curriculum
<b>PIP</b>	<b>Professional Instructional Processes</b>
UTEMI	Usage of Tools in Enhancing Mathematics Instruction
ACLE	A Conducive Learning Environment
MMT	Meaningful Mathematical Tasks
TR	Teacher's role
LR	Learner's role
AMI	Analysis of the Mathematics Instruction

**Table 2.** Degree of Perception and Pedagogical Knowledge Category

Scale	Perception	Category
1.00 – 1.99	Very Low	Weak
2.00 – 2.99	Low	Moderate
3.00 – 3.99	High	Good
4.00 – 5.00	Very High	Excellent

In the second stage, the survey method was employed using the constructed questionnaire about the pedagogical standards for teaching mathematics. This was administered by post to 224 secondary schools and 108 primaries selected randomly throughout Malaysia. A total of five mathematics teachers from each selected school were asked to respond to the mailed questionnaire. However, only 73.2% or 820 secondary mathematics teachers and 66.8% or 361 primary mathematics teachers responded to the questionnaires.

### 3. Findings of the Study

The findings of this study were analyzed statistically (descriptive) on the four components of the pedagogical standards for teaching mathematics. Further, an exploration of the findings using the Structured Modelling Equation employing the Partial Least Squares Method was carried out to obtain the 'Pedagogical Standards for Teaching Mathematics Model' (Diagram 1).

#### 3.1. Profiles of the Respondents

Table 3 shows the detailed profiles of the mathematics teachers who took part in this study. Based on gender, there were 888 female respondents (75.2%) and 293 male respondents (24.8%) involved in this study. Ethnically, there were 842 Malay respondents (71.3%), 224 Chinese respondents (18.9%), 104 Indian respondents (8.8%) and 11 respondents from other ethnicities (1.0%). Almost 90% of the secondary mathematics teachers and 36.3% of the primary mathematics teachers were first degree holders with education. Among the secondary mathematics teachers, 528 (64.4%) were graduates who majored in mathematics while the rest were graduates who majored in non-mathematics fields. Among the primary

mathematics teachers, 183 (50.7%) graduated with an option in mathematics while 178 (49.3%) graduated with a non-mathematics option. It was also discovered that 586 (71.5%) secondary mathematics teachers and 202 (55.9%) primary mathematics teachers were between 31 and 50 years old. As far as the teaching experience was concerned, 516 (62.0%) secondary mathematics have between one to ten years of experience in teaching KBSM Mathematics while 747 (91.1%) teachers claimed to have between one to ten years of teaching Additional Mathematics. Among the primary mathematics teachers, 209 (57.9%) of them claimed to have between one to ten years of teaching KBSR mathematics while 152 (42.9%) teachers have teaching experiences of more than 10 years.

**Table 3.** Profiles of Secondary and Primary Mathematics Teachers

Profile	Secondary		Primary		Total
	No.	Percentage	No.	Percentage	
<b>Gender</b>					
Male	188	22.7	113	31.3	293
Female	640	77.3	248	68.7	880
<b>Ethnicity</b>					
Malay	651	77.3	191	22.7	842
Chinese	136	60.7	88	39.3	224
Indian	27	26.0	77	74.0	104
Others	6	54.5	5	45.5	11
<b>Major</b>					
Mathematics	528	64.4	183	50.7	711
Non-mathematics	292	62.1	178	37.9	470
<b>Age</b>					
< 31 years	234	59.5	159	40.5	393
> 31 years	586	74.4	202	25.6	788
<b>Teaching Experience</b>					
KBSM (1-10 years)	516	62.9	-	-	820
KBSM > 10 years	304	37.1	-	-	
KBSR (1-10 years)	-		209	57.9	361
KBSR > 10 years	-		152	42.1	

### 3.2 Standards for Teaching Mathematics Components

3.2.1. *Professional Attributes Component.* Table 4 shows the mathematics teachers' perception of the professional attributes component. There are three elements in this component which are self-attribute, professional development and school and community's responsibility. The overall mean score for this component is 4.06 (SD= 0.51 for the secondary teachers and 4.12 (SD = 0.46) for the primary teachers. This indicates that the level of perception of the respondents on this component is high and the teachers' knowledge is categorized as excellent. For the elements of self-attribute, professional development and school & community's responsibility the mean scores and standard deviations for secondary/primary teachers are (Mean = 4.29/4.20; SD = 0.50/0.45), (Mean = 4.08/4.10; SD = 0.54/0.49) and (Mean =

3.80/4.05; SD = 0.67/0.56) respectively. Therefore, it could be said that the respondents' levels of perception of the elements of self-attributed and professional development are very high and mathematics teachers' knowledge can be categorized as excellent.

**Table 4.** Secondary and Primary Mathematics Teachers Perception on the Professional Attribute Component

Component	Secondary		Primary	
	Mean	SD	Mean	SD
Self-attribute	4.29	0.50	4.20	0.45
Professional Development	4.08	0.54	4.10	0.49
School & Community's Responsibility	3.80	0.67	4.05	0.56
Overall	4.06		4.12	

**3.2.2 Professional Practices Component.** Table 5 shows the three elements of the professional practices component which are mathematics instructional planning, monitoring and evaluation and pedagogical implementation in the teaching and learning of mathematics. Overall, the mean scores for this component are 4.04 (SD = 0.53) and 4.15 (SD = 0.47) for the secondary and primary teachers respectively. This shows that the mathematics teachers' level of perception is very high and their knowledge can be categorized as excellent. For each of the element or construct, the mean scores and standard deviations for secondary/primary teachers are 4.08/4.16 (SD = 0.54, 0.49), 3.99/4.12 (SD = 0.59, 0.47), 4.06/4.14 (SD = 0.56, 0.52) respectively. Among the secondary mathematics teachers, the respondents show a high level of perception concerning the elements of mathematics instructional planning and pedagogical implementation in the teaching and learning of mathematics while the teachers' knowledge can be categorized as excellent.

**Table 5.** Secondary and Primary Mathematics Teachers' Perception of the Professional Practice Component

Component	Secondary		Primary	
	Mean	SD	Mean	SD
Mathematics Instructional Planning	4.08	0.54	4.16	0.49
Monitoring and Evaluation	3.99	0.59	4.12	0.47
Pedagogical Implementation in the Teaching and Learning of Mathematics	4.06	0.56	4.14	0.52
Overall	4.04		4.15	

**3.2.3 Professional Knowledge Component.** Table 6 shows the five elements associated with the professional knowledge components which are mathematics content knowledge, knowledge on the application of ICT in mathematics instruction, knowledge of learners, knowledge of the curriculum and knowledge on intellectual quality. Overall the mean scores for this component are 3.94 (SD = 0.54) for the secondary teachers and 4.04 (SD = 0.46) for the primary teachers. This indicates that level of perception for this component is high and the secondary teachers' knowledge is deemed good while the primary teachers' knowledge is categorized as excellent. Only the element of content knowledge is reported to be at a very high level with a mean score of 4.11 (SD = 0.59) while the teachers' knowledge is reckoned to be excellent. For the secondary teachers, the other four elements are said to have a high level of perception with mean scores of 3.70 (SD = 0.69), 3.92 (SD = 0.58), 3.98 (SD = 0.70), and 3.99 (SD = 0.61) respectively while the teachers' knowledge is deemed good. For the primary teachers, only the element of ICT with a mean score of 3.73 (SD = 0.64) can be said to have a very level of perception and the teachers' knowledge can be categorized as good. The other four elements; mathematics content knowledge (mean = 4.12, SD = 0.49), knowledge of learners (mean = 4.07, SD = 0.50), knowledge of the curriculum (mean =

4.17, SD = 0.55), and knowledge on intellectual quality (mean = 4.06, SD = 0.51) too have a very high level of perception among the primary teachers while their knowledge on the four elements can be described as excellent.

**Table 6.** Secondary and Primary Mathematics Teachers' Perception of the Professional Knowledge Component

Component	Secondary		Primary	
	Mean	SD	Mean	SD
Mathematics content knowledge	4.11	0.59	4.12	0.49
Knowledge of the application of ICT in mathematics instruction	3.70	0.69	3.73	0.64
Knowledge of learners	3.92	0.58	4.07	0.50
Knowledge of the curriculum	3.98	0.70	4.17	0.55
Knowledge of intellectual quality	3.99	0.61	4.06	0.51
Overall	3.94		4.04	

3.2.4 *Professional Instructional Processes Component.* Table 7 shows the six elements associated with the component of professional instructional processes namely knowledge on the application of tools in enhancing the mathematics instruction, knowledge of a conducive environment, knowledge of meaningful mathematical tasks, knowledge of the teacher's roles, knowledge of the learner's roles and knowledge of how to analyze the mathematics instruction. Overall, the mean scores for this component are 4.07 (SD = 0.53) for the secondary teachers and 4.05 (SD = 0.43) for the primary teachers. This indicates that for this component, the degree of approval for both sets of teachers is very high indeed, while their knowledge can be categorized as excellent. As for the element of application of tools in enhancing the mathematics teachers is concerned, the level of perception can be considered high for both secondary (mean = 3.76, SD = 0.62) and primary (mean = 3.72, SD = 0.55) teachers. It also revealed that their knowledge concerning this element deemed good. For the element of knowledge concerning the conducive environment, the mean scores for the secondary and primary teachers are 4.02 (SD = 0.62) and 4.03 (SD = 0.62) respectively. Similarly, the mean scores for the element of knowledge of meaningful mathematical tasks are 4.09 (SD = 0.59) and 4.10 (SD = 0.48). As for the knowledge about the teacher's roles, the mean scores are 4.2 (SD = 0.55) and 4.19 (SD = 0.48). Meanwhile, the mean scores for the element of the learner's roles, are 4.22 (SD = 0.58) and 4.17 (SD = 0.50) respectively. Lastly, the mean scores for the element of knowledge on the analysis of the mathematics instruction are 4.13 (SD = 0.62) and 4.12 (SD = 0.51) respectively. Moreover, the teachers' knowledge regarding this component is excellent.

**Table 7.** Secondary and Primary Mathematics Teachers' Perception on the Professional Instructional Processes Component

Component	Secondary		Primary	
	Mean	SD	Mean	SD
Knowledge of the application of tools in enhancing the mathematics instruction	3.76	0.62	3.72	0.55
Knowledge of a conducive environment	4.02	0.62	4.03	0.50
Knowledge of meaningful mathematical tasks	4.09	0.59	4.10	0.48
Knowledge of the teacher's roles in the mathematics instruction	4.20	0.55	4.19	0.48
Knowledge of the learner's roles during the mathematics instruction	4.22	0.58	4.17	0.50
Knowledge about the analysis of the	4.13	0.62	4.12	0.51

mathematics instruction		
Overall	4.07	4.05

The overall mean scores for the four components are 4.06 and 4.09 respectively for the secondary and primary teachers. This indicates that both sets of mathematics teachers have a very high degree of approval for these components of the pedagogical standards for teaching mathematics. In tandem, their knowledge too can be categorized as excellent.

3.2.5. *Structural Equation Modelling for the Pedagogical Standards for Teaching Mathematics.* In the actual research involving 820 secondary mathematics teachers and 361 primary mathematics teachers, *Kuder-Richardson* and *Alpha Cronbach* coefficients are used to determine the reliability of the questionnaire items relating to all constructs: Professional Practices (PP), Professional Attributes (PA), Professional Knowledge (PK), Professional Instructional Processes (PIP) and Pedagogical Standards for Teaching Mathematics (PSTM). For the secondary teachers, the coefficient value is between 0.859 and 0.934 while for the primary teachers, the coefficient value is between 0.734 and 0.959. This range of values exceeds the range of values between 0.70 and 0.80 which is considered good as proposed by Kaplan & Saccuzzo [10]. Thus, all the items deemed reliable.

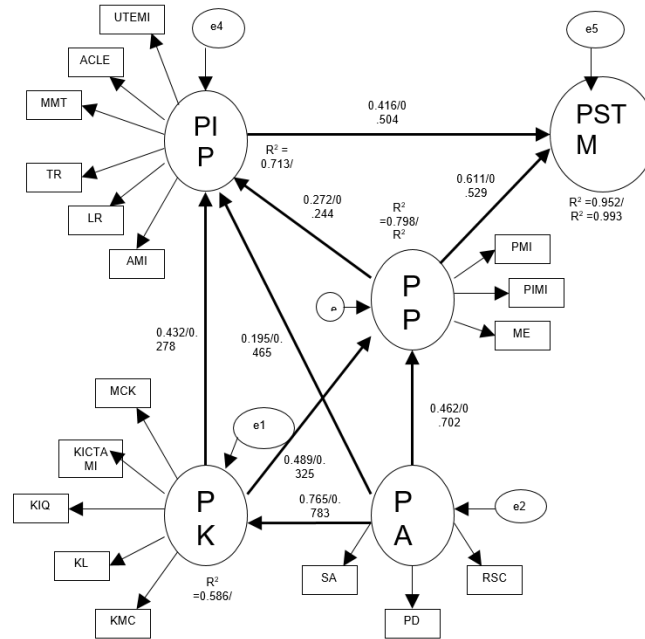
This study used the reliability value of the Dillon-Goldstein's composite variables indicator and Fornell & Larcker's extracted mean variance to test the reliability and fitness of the external structural equation modeling as suggested by Lohmoller et al. [11]. The reliability coefficient values for the five constructs of the tested external model are as in Table 8.

**Table 8.** Reliability coefficient values for the external model of PSTM

Construct	Dillon-Goldstein ( $\geq 0.70$ )	
	Secondary	Primary
Professional Practices (PP)	0.9478	0.8929
Professional Attributes (PA)	0.9205	0.8599
Professional Knowledge (PK)	0.9280	0.7481
Professional Instructional Processes (PIP)	0.7499	0.7381
Pedagogical Standards for Teaching Mathematics (PSTM)	0.9835	0.8196

The Dillon-Goldstein's coefficient values obtained from the study on the primary and secondary mathematics teachers exceed 0.70. Fornell & Larcker's value of 0.9013 also exceeds 0.70. Hence, based on the suggestion made by Lohmoller [11] concerning the acceptable values to be reckoned as significant, the developed pedagogical standards for teaching mathematics model in this study can be accepted. As for the external model that includes PP, PA, PK, PIP and PSTM, the Fitted Index (FI) is used in determining the acceptance of the model. The calculation of FI depends on the value of the extracted mean-variance and the determination coefficient. In this study, the FI values for the secondary and primary mathematics teachers are 0.8216 and 0.8666 respectively. According to Tenenhaus et al. [12], FI represents the overall fitted degree of a developed model. If the FI is more than 0.75, the model is considered fit. Based on the values of the FI obtained from this study that is 0.8216 and 0.8666, the internal model of the developed Pedagogical Standards for Teaching Mathematics (PSTM) can be accepted.

The Pedagogical Standards for Teaching Mathematics Model that involve PP, PA, PK PPI and PSTM is shown in Diagram 1.



**Diagram 1.** Pedagogical Standards for Teaching Mathematics (PSTM) Model

The external model equations that have been successfully developed for secondary and primary schools' are as follows:

Secondary mathematics teachers:

Primary mathematics teachers:

$$PSTM = 0.611 PP + 0.416 PPI \quad (i)$$

$$PSTM = 0.529 PP + 0.544 PPI \quad (i)$$

$$PP = 0.462 PA + 0.489 PK$$

$$(ii) \quad PP = 0.454 PA + 0.465 PK \quad (ii)$$

$$PK = 0.765 PA$$

$$(iii) \quad PK = 0.783 PA \quad (iii)$$

$$PPI = 0.272 PP + 0.195 PA + 0.432 PK \quad (iv) \quad PPI = 0.244 PP + 0.465 PA + 0.278 PK \quad (iv)$$

These two sets of external model equations demonstrate that a causal relationship between the five latent variables that were developed in this model does exist. The structural equation modeling developed shows a direct relationship between PP against PSTM and as well as between PPI against PSTM. All of the regression coefficients for the exogenous and endogenous variables in the model display significant statistical testing values. The causal relationship mentioned earlier refers to the direct effect of the latent variable PP on PSTM and PPI on PSTM. The estimated correlational and regression coefficients values obtained between PP and PPI against PSTM are 0.611;0.529 and 0.416;0.544 respectively. Each of PP and PPI correlated significantly with PSTM. This explained vividly that PP and PPI are the main components in developing the pedagogical standards for teaching mathematics. The regression coefficient value indicates that a unit change in PP would cause an increase of 0.416;0.529 unit change in PSTM while a unit change in PPI would cause an increase of 0.611;0.504 unit change in PSTM.

The indirect effect shown in the PSTM model is the effect of PK on PSTM through the endogenous variables PP and PPI. The indirect relationship between PA and PSTM can also be found through the mediator variables PP and PPI.

#### 4. Conclusion

The study was carried out with reference to the standards for teaching mathematics put forward by NCTM (USA), AAMT (Australia), and TDA (United Kingdom). However, these standards were not tested statistically as far as the significance and the suitability of the standards' constructs was concerned. As an example, the six standards for teaching mathematics espoused by NCTM came about from discussions among a group of experts that comprised teachers, teacher educators, administrators, researchers, and mathematicians. From these discussions, 30,000 drafts of the standards for teaching mathematics constructed were distributed throughout the United States. This was followed by presentations at various mathematics education conferences. In all, 650 individuals and 70 groups had voiced out their opinions on the standards for teaching mathematics. The feedback was given and the issues raised were used to improve the standards for teaching mathematics to be used in America.

AAMT is an Australian professional body of about 5,500 members that comprises mathematics teachers, teacher educators, and administrators at every level. The Standards for Excellence in Teaching Mathematics was constructed jointly by AAMT and University of Monash through a research project financed by the *'Industry Research Grant'*. This project utilized the *'grounded research methodology'* and was carried out continuously to obtain the mathematics teachers' feedbacks. A *'Teacher Focus Group'* which comprised 50 members was formed in each province. This group held discussions for three years in order to produce the *'Standards for Excellence in Teaching Mathematics in Australian Schools'* [3]. Three components of the standards were identified but were not tested statistically in determining the suitability of the components.

The model that is produced from this study is known as the Pedagogical Standards for Teaching Mathematics or in short PSTM. This model refers to the level of knowledge about professional knowledge (PK), professional practices (PP), professional attributed (PA) and professional instructional processes (PIP) that a mathematics teacher must have in order to make a transformation in carrying out these standards before, during and after the mathematics instruction. The finding from the study revealed that the secondary and primary mathematics concurred highly with PA, PP, and PPI. However, the respondents' level of knowledge on PK was only satisfactory. Based on the mathematics teachers' perception, the mean scores for the overall mathematics pedagogical standards were 4.09 for the secondary teachers and 4.06 for the primary teachers. This shows that the respondents displayed a very high degree of approval towards the PSTM. They concurred that the four knowledge components of PK, PP, PA, and PPI formed a crucial knowledge for mathematics teachers to achieve excellence in teaching.

The instrument for the Standards for Teaching Mathematics's Model Instrument that had been developed was successful in exploring and testing statistically the model that was based on the four components namely, professional knowledge, professional attribute, professional practice and professional process of instruction. The composite reliability indices of the indicator variables that consisted of constructed items were tested and the results indicated that the items fitted nicely into the Pedagogical Standards for Teaching Mathematics (PSTM) model. Testing on the five constructs of PP, PA, PK, PPI, and PSTM showed that values of the tested reliability coefficients satisfied the condition to be accepted as the constructs in the Standards for Teaching Mathematics Model. The results of the statistical test using the Structural Equation Modelling (SEM) based on the Partial Least Squares (PLS) method showed that the model could be fitted significantly. Consequently, the four components plus the items constructed could be used as indicators for the mathematics teachers' standards for teaching and in determining the excellent level of mathematics instruction in Malaysia.

The component of 'Professional Practices' (PP) is seen as a direct contributor towards PSTM while 'Professional Knowledge' (PK) gives an indirect contribution via 'Professional Attributes' (PA) and 'Professional Processes of Instruction' (PPI). This means that PA gives a direct contribution towards PPI and PPI, in turn, gives a direct contribution towards PSTM.

To achieve 'Professional Practice' (PP) a teacher needs to have 'Professional Attribute' (PA) and 'Professional Knowledge' (PK). These practices of PA and PK give indirect contributions towards PSTM. 'Professional Knowledge' is seen as a direct contributor towards 'Professional Process of Instruction' (PPI) and 'Professional Practice' (PP). Nevertheless, PK also contributes indirectly towards PSTM but through PA and PPI.

Furthermore, 'Professional Knowledge' (PK) and 'Professional Attribute' (PA) are looked upon as the pillars for 'Professional Practice' (PP) and 'Professional Process of Instruction' (PPI) in improving the quality of mathematics instruction. For these two components to be implemented successfully, the mathematics teacher needs to have knowledge of mathematical content, mathematics curriculum, tools of technology, the learners, the learners' intellectual qualities while delivering the instruction as well as displaying concerns for them, enhancing his or her professional development from time to time and contributing significantly to school and community in improving the level of mathematics achievement.

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The banner features a dark blue background with a satellite view of Earth. On the left, there are three circular logos: the top one is 'ECS' in a white circle, the middle one is 'The Electrochemical Society' with a stylized 'ECS' logo, and the bottom one is 'THE KOREAN ELECTROCHEMICAL SOCIETY'. The main text in the center reads 'Joint International Meeting PRIME 2020 October 4-9, 2020' in white and blue. Below this, a blue bar contains the text 'Attendees register at NO COST!' in white. On the right side, there is a large white logo for 'PRIME' with a stylized 'P' shape above it, followed by 'PACIFIC RIM MEETING ON ELECTROCHEMICAL AND SOLID STATE SCIENCE' and '2020' in white. At the bottom right, a blue bar contains the text 'REGISTER NOW' in white with a white arrow pointing right.

# An early start to STEM education among year 1 primary students through project-based inquiry learning in the context of a magnet

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**Abstract.** For the needs of the 21st century, the Government of Malaysia has conceptualized the Malaysia Education Blueprint 2013-2025 which embodies 11 strategic and operational shifts. In Shift 1, it is emphasized that the quality of Science, Technology, Engineering, and Mathematics (STEM) Education will be enhanced. This study employed the mixed-method approach using the “one-group pre-test and post-test design”. Accordingly, this paper describes the pedagogical practice of Project-based Inquiry Learning (PIL) which promotes STEM Education among Year 1 students in the move to progress in tandem with Shift 1. Specifically, using the context of a magnet which has been stipulated in the Primary School Standard Curriculum, Year 1 students experienced the STEM Education through the STEM Pedagogy in which they raised questions upon the presentation of a relevant stimulus (Inquiry Phase), explored the ways in which a train carriage or coach could be assembled by means of recycled materials and magnets (Exploration Phase), designed a train carriage (Design Phase), and ultimately reflected on their inventions (Reflection Phase). The cognitive and affective impacts through the use of this Project-based Inquiry Learning are presented. Implications for the teaching and learning of science are discussed within the context of STEM Education.

## 1. Introduction

In the quest of becoming a developed nation by 2020, Malaysia has given great emphases on education. Moreover, given that science, technology, engineering and mathematics education plays a big role as the catalyst in meeting the challenges and demands of our present and future economy, Malaysian government has instituted a number of related policies such as the 60:40 Science/Technical: Arts (60:40) Policy in 1967. Statistics indicate that, as of 2014, only about 45% of students graduated from the higher secondary schools were from the Science stream, including technical and vocational programmes. Additionally, the percentage of secondary school students who chose not to pursue the Science stream despite meeting the requirement based on their Form 3 National Standardised Examination (PMR) had increased to approximately 15% [1].

Meanwhile, in the context of rising international education standards and the aspiration of better preparing Malaysia’s children for the needs of the 21st century, the Government of Malaysia has conceptualized the Malaysia Education Blueprint 2013-2025 [2] which embodies 11 strategic and operational shifts. Essentially, there are five outcomes that the Blueprint aspires to achieve for the



Malaysian education system as a whole: access (i.e. 100% enrolment across all levels from preschool to upper secondary by 2020), quality (i.e. top third of countries in international assessments such as PISA and TIMSS in 15 years), equity (50% reduction in achievement gaps: urban-rural, socioeconomic and gender, by 2020), unity (an education system that gives children shared values and experiences by embracing diversity), and efficiency (i.e. a system which maximises student outcomes within current budget).

Research indicates that when children engage in projects in which they conduct investigations and/or involve in creation or invention around their personal questions, their intellectual capacities are very likely to be provoked and utilized [3–5]. Furthermore, engagement in projects places children in an active and interactive role where they take responsibility and initiative in inquiring by means of generating questions which they would like to seek answers to; exploring by means of collecting relevant data or information culminating in a suitable design or procedures; investigating based on the procedures or inventing based on the design; and showcasing or reporting their work [4], and ultimately yields better school participation and achievement in the long term [5].

Ong et al. [6] concocted a STEM pedagogical approach termed as Project-based Inquiry Learning or PIL which entails 4 phases, namely Inquiry, Exploration, Invention, and Reflection. Using the context of a ship, Ong et al. [7] illustrate that the inquiry-based learning centres on “Inquiry” regarding a ship, culminating in a question on “how to build a ship?” which in turn, leads to the “Exploration” of the phenomenon on floating and sinking, and of information pertaining to ships of different shapes and sizes which concludes with a design of a ship. Such design will then be accomplished and materialized through project-based “Invention”, and this is then followed by showcasing and reflection of the completed projects/inventions/investigations, and appreciation of the projects by peers. The STEM integration in this Project-Based Inquiry Learning encompasses the *science* concepts on buoyancy and energy, the *technology* which is reflected in building ships, the *mathematics* which is manifested in size and symmetry in ships, and *engineering* which involves designing of a ship.

## 2. Methods

### 2.1 Research Design

This study employed the mixed-method approach using the “one-group pre-test and post-test design” in which quantitative attitudinal data were collected and then triangulated by interview data which mainly solicit children’s view on their self-perceived understanding [8]. In the qualitative data, interview approach was used by means of interviewing seven randomly selected students from the single group students after they have undergone the learning of magnet using PIL approach to ascertain their interest towards the learning of magnet based on Project-based Inquiry Learning and equally, their understanding of the concept of magnet and their reflection. The reflection of a science teacher (the first author) in conducting a lesson on magnet through the using of a Project-based Inquiry Learning was shared.

### 2.2 Sampling

A purposive sampling was used as selection criteria that only involves a school namely Primary School A (name withheld for anonymity purpose) in the Ipoh district where students were in Year 1 class. Table 1 provides a breakdown of the sample by gender. Overall, there were 27 years 1 students who participated in this study.

**Table 1.** Breakdown of sample based on gender

Gender	Total
Boys	15
Girls	12

### 2.3 Instrumentation

The questionnaire contains two parts. Part 1, consisting of three-point Likert-scale items, measures students' attitudes towards learning of science through the Project-based Inquiry Learning approach, while Part 2, consisting of 3 interview questions: (a) Do you enjoy making train carriage? (2) What have you learned about magnets from the train project? (3) How can you improve your train (invention)? The reliability of Part 1 of the Questionnaire was established using the data set of 27 students of which the Cronbach's alpha was measured at 0.917, indicating that the questionnaire has high internal reliability [9].

### 2.4 Lesson Plan on Project-Based Inquiry Learning Model

The PIL-based lesson plan on Magnet, carried out for the duration of 3 weeks, entails four major steps/phases. In the first phase (inquiry), the teacher draws the attention of students to the various pictures and video clips of a train as a stimulus, and students are asked to state what they knew about the train and subsequently, what they want to know more about the train. They also explore how magnet could be used to connect the carriages of the train. In the third phase (design), students build and design train carriages (i.e., engineering inaction) based on their earlier sketches produced in the second phase.

### 2.5 Data Gathering and Analysis Procedures

Part 1 of the questionnaire was administered to the students before and after the lesson so as to obtain feedback on their attitudes towards learning science through Project-based Inquiry Learning. The data collected were analyzed using a paired samples t-test. Meanwhile, seven students were interviewed based on the 3 interview questions in Part 2 so as to obtain feedback on their interest towards learning science and the knowledge acquired, and their reflection on the aspects their invention could be improved. The interview data will be transcribed and analyzed thematically.

## 3. Results

*Research Question 1: To what extent does the Project-Based Inquiry learning increase Year 1 students' attitudes towards learning science?*

**Table 2.** Results Obtained from t-Test for Paired Samples (Students' interest in learning Science)

Attitudes Before PIL			Attitudes After PIL			T	p
N	Mean	SD	N	Mean	SD		
27	11.04	4.49	27	24.00	0.00	14.99	.000

A paired-samples t-test was conducted to compare the self-perceived attitudes towards science before and after the magnet science lesson using Project-based Inquiry Learning (PIL). There was a significant difference in the scores for the attitudes towards science before magnet lesson using PIL (M=11.04, SD=4.49) and the attitudes towards science after the magnet lesson using PIL (M=24.00, SD=0.00) conditions;  $t(26)=14.99$ ,  $p < .001$ . These results suggest that Project-based Inquiry Learning does have an effect on students' attitudes towards science. Specifically, our results suggest that when Project-based Inquiry Learning was employed, the attitudes towards science increases.

*Research Question 2: To what extent does the Project-Based Inquiry learning increase Year 1 students' students' interest, understanding about magnet and reflective ability?*

Based on the responses of seven students to Question 1, resounding major theme emerged, which has students enjoyed science. The enjoyment was expressed in different forms such as they enjoyed making and creating their own train carriage models, and enjoying the lesson as a whole. This theme is supported by the following transcripts of the interview data:-

- Yes, I enjoy making the train carriage.* (Student A)  
*I like to make train carriage.* (Student B)  
*Yes, I want to make train carriage again.* (Student C)  
*Yes, I was very excited making train carriage.* (Student D)  
*Yes, I enjoyed [the lesson].* (Student E)  
*Oh, I enjoyed making the train carriage.* (Students F & G)

When asked about what they have learned which was posted as Question 2, the responses revealed students' understanding of magnets which could be categorized into 3 general themes:

- **The use of magnet**

Students A, D and G seem to show the understanding that magnets are able to connect the carriages, although the way in which the connection may occur was not explicated specifically.

- Yes, I understand how to use magnets to connect train carriage.* (Student A)  
*The magnet can connect the carriages.* (Student D)  
*The magnet can attract the train carriage.* (Student G)

- **The things that a magnet attracts**

One of the understandings which emerged from the interview data is that of the things which a magnet attracts. During the exploration phase, students explored about the magnets, and it was specifically explicated in the interview data that ...

- The magnet can attract iron.* (Student B)

- **Differing poles of magnets attract**

Students did learn the basic facts of a magnet such as same poles repel while opposing poles attract each other. This is supported by the following transcript:

- Magnets can attract each other if [they are of] different poles.* (Student C)

When asked how the students could improve their train (invention) which was posted as Question 3 as a means to solicit their reflection, the responses could be categorized into three aspects in which the students would like to see improvement of their designs. The three aspects are:

- **Loads**

Students would like to see that improvement could be made in terms of load. They would like to see an improvement is made to their design so that their invention would be able to withstand and carry more loads as succinctly supported by the following transcription:-

- My train carriage will carry more goods.* (Students A & F)

- **Speed**

Meanwhile, the majority of the students interviewed expressed an improvement in the speed that the train could move. They have not have learned, let alone explored in the science classrooms about friction, axles, and wheels although they have encountered them in the real-life situation, the following expressions should someday be realized:-

- My train carriage will move faster.* (Student B)  
*My train carriage will be much ... faster.* (Student C)  
*My train can move faster.* (Student D)  
*My train carriage will move faster.* (Student E)  
*My train magnet carriage moves faster.* (Student G).

#### • Size

Finally, the third aspect of improvement to the invention is in terms of the size of the train. They would like to see that, in future, they are able to build a bigger train as depicted in one of the transcriptions:-

*My train carriage will be much bigger and faster.* (Student C)

#### 4. Reflection and Conclusion

The findings of this study indicated that students perceived that their attitudes towards learning Science have been elevated through the Project-based Inquiry Learning, evident in the significant differences between self-perceived attitudes towards science before and after learning science through PIL. Additionally, students' understanding of the concept at hand has also been elevated and the understanding was categorized into three themes, namely the use of a magnet, the things that a magnet attracts, and differing poles of a magnet attract. Students also indicated that should they asked to improve on their designs, improvements to the loads that a train may carry, the speed that a train travels, and the size of a train would be their priority.

There are some pedagogical implications for teachers based on the experience of conducting the current study. Firstly, the teacher should allow students the opportunity to raise questions upon the presentation of a relevant stimulus train. Project-based Inquiry Learning is one of the ways teachers could do so. Besides, the teacher needs to be able to handle student questioning and be tactful in convincing students which question should be explored and investigated. In this case, how to make a train using magnets was the question being explored and investigated to which students did enjoy themselves and learn the concept at hand (i.e., magnets). As evident in this research, teachers should be convinced on the beneficial use of Project-based Inquiry-based Learning as it not only enhances students' understanding of the concept at hand, it also increases creativity students when Project-based Inquiry Learning method is maximally utilized due to the higher level of student engagement and on-task behavior.

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Process skills approach to develop primary students' scientific literacy:  
A case study with low achieving students on water cycle

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# Process skills approach to develop primary students' scientific literacy: *A case study with low achieving students on water cycle*

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**Abstract:** The results of the Program for International Student Assessment (PISA) study on the scientific literacy of Indonesian students since the year 2000 have been still far below the international average score of 500. This could also be seen from the results of the science literacy test of 5th-grade students of primary school in Indonesia which showed that 60% of students are still at level  $\leq 3$  (value  $< 500$ ). The students' science literacy skills need to be improved by applying learning with a process skills approach. This study aims to describe the findings of classroom action research using a process skills approach to the science literacy level of primary students ( $n = 23$ ). This research was conducted in 2 cycles with stages of planning, implementation, observation, and reflection. Students' ability in scientific literacy was measured by using description and subjective tests of context domains, knowledge, competencies, and attitudes. In this study, researchers found an improvement in students' science literacy skills when learning using a process skills approach. In addition, students' scientific attitude is also more positive. In activities for learning science, students should be challenged as often as possible so that they have more practice using their scientific knowledge and skills to solve problems presented by teachers in the classroom.

## 1. Introduction

Mastering literacy is important for all people in order to be able to compete in the global era both as members of society, citizens, and citizens of the world [1-3]. Every citizen has a scientific literacy ability which allows them to survive in the wild as well as in the workplace, with the knowledge, understanding, skills, and values that make up that competence. Literacy activities are more than just reading and writing, and include thinking skills using knowledge sources in print, digital, visual, and auditory [4].

Scientific literacy can be trained through studying. According to King, the purpose of teaching science is producing students who have competence in scientific literacy. The skills of teachers in planning the learning process is the key to successful learning [5]. One alternative way to improve literacy abilities of science students in the learning process is by applying the process skills approach. Scientific literacy can be enhanced through research-based learning, including *discovery learning* [6]. According to Rauf, et al, [7], process skills in science are very important in learning how to gain knowledge. Aktamis and Ergin [8] stated that process skills include the skills of each individual that are used in daily life which can improve the quality and standard of life by understanding the nature of science. Ango [9] stated that science process skills are basic and



essential components of the process of learning science under the guidance of a teacher. In line with this opinion, Ibrahim, et al., [10] stated that mastering process skills mean mastering skills to conduct research and solve problems. Problem-solving and research skills are life skills and are the highest learning outcomes for students.

This research aims to describe the level of scientific literacy of primary students in studying science with a process skills approach. The results of this research are expected to contribute to the improvement of science students' scores in scientific literacy in Indonesia conducted by PISA every 3 years. The results of the 2009 PISA study found that the average literacy score in science was 383, literacy in reading was 402 and literacy in math was 371 [11].

The results of research that have been conducted by Foulds and Rowe [12] show that when science teaching and increasing process skills are integrated into the learning activities of students, this can improve the students' understanding. Gormally, Cara., etc. [13] in their research found an increase in the scientific literacy of students using lab inquiry. The research of Sullivan [14] found that an understanding of environmental robotics with an open approach is able to encourage students to use scientific literacy and process skills as well as improving understanding. Remziye, et al [15] in their research found that learning by using inquiry approaches can improve process skills and attitudes about science.

Previous researchers, in their research on high school and college students, implemented inquiry-based activities which necessitate process skills to enhance understanding of what is being studied. In this study, researchers use a process skills approach to measure the scientific literacy intelligence of science students, in particular, primary school students. Scientific literacy includes context, knowledge, competence, and attitude, which can only be measured by testing high-level thinking ability. Scientific literacy is regarded as a key learning outcome in education for all students aged 15 years, regardless of whether they continue studying science or not, for participating in society [16]. Although not yet 15 years of age, primary students need to be introduced to scientific literacy in the context appropriate to their cognitive development, for example, their immediate environment and personal setting. The students who were the subjects of this research at a minimum had access to an on-site classroom and learning resources. In addition, their initial scientific literacy results were very low. Teaching that has occurred up until this point centered on the teacher and the students were not actively involved in the learning process. As a result, students are not used to using scientific knowledge through a series of scientific activities. In addition to this, measuring the students' knowledge was generally done focusing on memorized information, so only lower level knowledge was being measured.

The focus of this study is to describe the scientific literacy ability of science students learning about the water cycle. Basic competencies include describing the need for water-saving and describing the process of the water cycle and the way that human activities that may be affected. The scientific literacy indicators that were observed include identifying scientific issues, explaining phenomena scientifically and using scientific evidence.

## **2. Research method**

This research is classroom action research with a descriptive, qualitative design, which aims to describe or reveal more deeply about the process and learning outcomes related to the scientific literacy level of primary school students. Before the action research began, students were given a pre-test and after the action research, they were given a post-test.

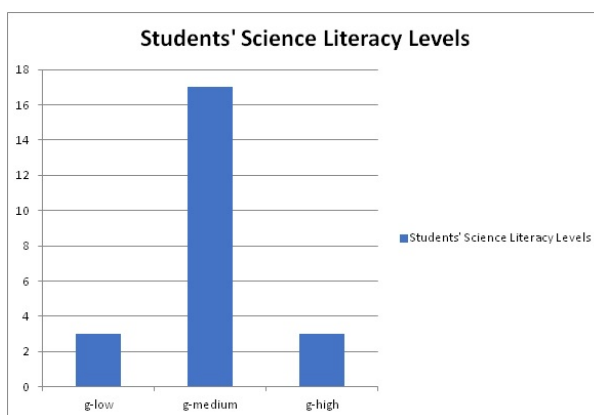
The subjects in this study were the 5th graders of Inpres Naikoten 1 Primary School, Kupang City, NTT Indonesia. There were a total of 23 students consisting of 12 boys and 11 girls studying water cycle. The subjects of the study were chosen after considering where the relevant needs were.

The research procedure included the planning phase, implementation, observation, and reflection. Instruments used in the research included scientific literacy tests, student activity observation sheets, and student science attitude questionnaires. Student activity observation sheets included formulating problems and hypotheses, using tools and materials as directed, observing,

analyzing data, and making conclusions. Student questionnaires were structured to determine students' opinions about vacant land empty of cultivated crops, excessive use of water, and so forth. The scientific literacy test was conducted twice; during the water cycle material and the material about the impact of human activities on the water cycle. The test was multiple choice. Here is an example of scientific literacy, which falls into the category of high-level thinking skills.

The multiple choice questions in each cycle were 10 questions; with 2 questions of level 1, 1 question of level 2, 2 questions of level 3, 1 question of level 4, 2 questions of level 5, and 2 questions of level 6. Before being used, the test was validated by 2 experts. The test was valid and needed only small revisions. The data about the scientific literacy level of students was analyzed descriptively. The indicators used to determine the success of this research was if there is an increase in the middle classification of scientific literacy level, 80% of students are able to answer questions at level 4 and the observation of scientific attitude reaches 80% (very good).

### 3. Results and Discussion



Data on the literacy test results in the areas of knowledge, context, and competency are presented as followed. It appears that students' science literacy ability in Cycle 1 learning is  $52.17\% \leq$  level 3 and  $47.83\%$  are at level 4. None can reach level 6. After learning cycle 2,  $8.70\%$  students are  $\leq 3$  and as many as  $91.30\%$  are at level  $\geq 4$ .

**Figure 1** shows the increase in students' science literacy levels in the range of  $(g) > 0.7$  (g-high) scale of 3 people,  $0.7 \geq (g) \geq 0.3$  (g-medium) of 17 people,  $G) < 3$  (g-low) as many as 3 people. After applying the process skills

approach, there is an increase in scientific literacy skills from cycle 1 to cycle 2. This result shows that by undertaking process skills activities that are hands-on, it increased student learning outcomes. In process skills activities, students were directly involved in activities such as watching videos about the water cycle, asking questions, conducting activities as directed, discussing observations and making conclusions. By watching the video and asking some questions students will construct their own thoughts and discuss this with their peers. This is in accordance with the opinion of Semiawan, et al., [17] who explained that process skills are associated with the physical and mental skills needed for the fundamental abilities possessed, controlled and applied in scientific activity when scientists find a new discovery. Skills-based learning in the science process is learning that integrates the skills of the scientific process into a presentation of the materials in an integrated way. This learning emphasizes the process of seeking knowledge rather than the transfer of knowledge, learners are viewed as the learning subjects that need to be actively involved in the learning process, and the teacher is only a facilitator who guides and coordinates learning activities.

The above explanation is supported by the statement of Jerome Bruner and his colleagues who provide important theoretical support known as discovery learning, which emphasizes the importance of helping students acquire knowledge in a way that can train students' intellectual abilities, stimulate their curiosity and motivate their competence. This is what is meant by acquiring knowledge through discovery learning. In his book *Toward a Theory of Instruction*, Bruner points out "if we teach science, we will not produce small life libraries about science, but we want to make children think mathematically for themselves and participate in the process of acquiring knowledge. Knowing is a process, not a product" [18].

The result of an increase in student scientific literacy through applying the process skills approach shows the effectiveness of the approach used in teaching. Information submitted by teachers to students about learning materials related to the concept of water cycle and saving water

can be applied to daily life and students can draw conclusions from the problems provided by teachers. This is supported by Piaget's theory which explains that the main factor that encourages the cognitive development of a person is the motivation or power from within the individual himself to want to learn and interact with his environment [19]. Therefore, in order for students to be motivated to learn, teachers must be responsible for conducting interesting lessons, one of which is by applying the process skills approach in learning science. The results of the science literacy of the students in the domain of knowledge are in line with the results of the attitude domain which shows a positive attitude. The results of the attitude towards science domain are presented in Table 1 below.

**Table 1.** Scientific literacy attitude domain

No.	Statement	%	Category
1	Create wastewater storage at home	97	Very Good
2	Get drinking water as much as possible and not drink it until it runs out	100	Very Good
3	Be indifferent when I see the tap running in the school toilet	98	Very Good
4	Do not bury plastic waste in the soil	97	Very Good
5	Always promote a water-saving attitude to friends	99	Very Good
6	There are no restrictions on groundwater drilling by the government	95	Very Good
7	Provide suggestions to parents to create a rain water catchment basin	97	Very Good
8	I chose to take a bath from the tub with a dipper rather than with a shower	100	Very Good
9	The government establishes a program of absorbing wells at several points of the city	96	Very Good
10	Turn off the water tap during brushing and washing hands	100	Very Good

Scientific literacy in the domain of science attitudes became very good in relation to their responses about wastewater capture, taking drinking water, not burying plastic rubbish, and so on. The results from this attitude domain can reawaken the active role of the students to acquire concepts from the learning activities, then the students can apply the concepts obtained to everyday life. This explanation is supported by Piaget's theory that the child builds his own knowledge from his own experience within his environment. In Piaget's view, knowledge comes from action, and cognitive development largely depends on how far children are actively manipulating and actively interacting with their environment. The tendency of primary school children is to move from the concrete things, and then look at needs in an integrated way. Based on the above trends then, learning is an active process, constructive, and goal-oriented, all of which depends on the mental activity of learners. The provision of direct learning experiences in science lessons is strongly emphasized through the use and development of process skills and scientific attitudes with a view to understanding concepts and solving problems [21]. This is in accordance with the student's activity observation results in Table 2.

**Table 2.** Student activity in classroom learning

No.	Student Activity	Percentage (%)
1.	Formulate questions	100
2.	Make a hypothesis	89
3.	Using tools and materials according to instructions	100
4.	Cooperate in the activities of observation	87
5.	Discuss and analyze the observation data	98
6.	Discussion to summarize	89

Based on Table 2 above, students were involved in scientific investigation activities  $\geq 80\%$ . The process skills approach integrated into science lessons can actively involve students in the learning process [17], as well as strengthening the revelation of Dimiyati and Mudjiono [20] on the advantages of science process skills. Providing opportunities for students to work with science, rather than just telling or listening to stories about science, can lead to more active students, as well as science process skills that can help students learn scientific processes and knowledge at the same time.

High student activity in this study is supported by several theories, such as Piaget, who states that learning is an active process, constructive, goal-oriented, and learning all depends on the mental activity of learners [21]. Bruner also revealed that discovery learning is the foundation of the discipline of science, the need for the active involvement of students in the learning process, and he believes that this actually takes place through personal discovery. The goal of education not only trains the knowledge base but also creates opportunities for students' invention and creativity [22]. Bruner suggests that students should learn through active participation with concepts and principles in order for them to gain experience, and conduct experiments that allow them to discover the principles themselves [23].

Jerome Bruner is a Harvard psychologist who provides important theoretical support for discovery learning, an instructional model that emphasizes the importance of helping students to understand the structure or key ideas of a discipline, the active involvement of students in the learning process and the belief that true learning takes place through personal discovery. Discovery learning emphasizes the inductive reasoning and investigation processes that characterize the scientific method [24].

The most visible and influential student activity is the discussion between peers and teachers. This is in line with what described by Vygotsky's theory which states that if children work or handle tasks that cannot be solved on their own, then they can be solved with the help of peers or adults.

#### 4. Summary

There is an increase in students' scientific literacy levels after they engage in lessons using the process skills approach. This happens because in the learning process the students are actively involved in learning both physically and mentally (hands-on activity) through observing activities, making inquiries, conducting activities as directed, analyzing data, and drawing conclusions. The students' scientific attitude also experiences positive development. This shows that the ability of scientific literacy can be increased through learning activities.

In order to increase scientific literacy, it is best if classroom learning is designed to be problem-solving and challenging to students. To present problems in the classroom, the teacher can present phenomenon from the surrounding the environment in the form of video or live activities, demonstration, and storytelling related to the topic being studied.

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