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DEVELOPMENT OF PASCAL PRINCIPLE ACTIVITIES USING THE STEM APPROACH AND UNDERGRADUATE PHYSICS STUDENTS' PERCEPTION TOWARDS THE ACTIVITIES

Nawwar Raihan Alias, Nurulhuda Abd Rahman*

Department of Physics, Faculty of Science and Mathematics, Sultan Idris Education University, 35900 Tanjong Malim, Perak, Malaysia
Corresponding author. Email: nurulhuda@fsmt.upsi.edu.my

ABSTRACT

The aim of this study was to develop Pascal Principle teaching and learning activities using the STEM approach and to determine the content validity and undergraduate Physics students' perception of the activities. This study was a developmental research using ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model to develop the activities. The population was 135 physics undergraduates in their fifth and seventh semester of study from one of the public universities in Malaysia. Data was collected using a questionnaire that was adapted from a standardised instrument and that was distributed using Google Form to the population together with a link to the activities. The response rate was 29.6% (40 respondents). Perception data were analysed descriptively using percentage for content, language, design, and interest. Result shows that the experts were 95.5% in agreement about the content validity of the activities. For the perception data, 98.5%, 99.5%, and 99.0% students have positive perceptions towards the content, language, and design, respectively. In addition, 96.3% show interest in the activities. In conclusion, the research succeeded in developing validated teaching and learning activities that use the STEM approach and that were perceived positively by physics undergraduates. The materials for the activities can thus be used as a teaching and learning resource in the classroom.

Keywords : *STEM approach, integrated STEM, Pascal principle, Jack hydraulic, perception*

I. INTRODUCTION

The Ministry of Education Malaysia's new Secondary School Curriculum Standards [8], with the acronym KSSM, demand that Science, Technology, Engineering and Mathematics (STEM) be part of a student's education. In science classes, a lesson using the STEM approach should integrate mathematics, technology, and engineering to support the learning of a science concept [7]. The STEM approach is the application and integration of engineering practices with the content and practices of science and mathematics to design technologies that solve real-world problems [9]. Some of the benefits of the STEM approach that are gleaned from the literature are that the approach motivates students and enhance their ability to apply their knowledge and understanding in real world contexts [5][6]. However, teachers are having difficulty in providing engineering activities even though students are excited to do so. There is also a lack of appropriate and meaningful tested resources since the STEM movement is a recent development in the Malaysian education scenario [2].

Thus, this study designed and developed engineering-infused physics activities on the topic of Pascal Principle particularly as applied in Hydraulic Jack. This topic is suitable for a STEM approach lesson as the concepts in the topic provided the scientific knowledge that can be applied in building a hydraulic bridge as the solution to a real-life problem. Using the 5E instructional model: Engage, Explore, Explain, Elaborate, & Evaluate [4], we embedded an engineering challenge in the 'Elaborate' phase so that the lesson incorporates engineering design processes which have six steps namely define problem, research, imagine, plan, create prototype, test prototype, and improve [14] and engineering practices (e.g., defining problem and generating solutions). Within the same lesson, students are learning the relevant concepts in the 'Explore' and 'Explain' phases. To ensure that our designed activities are well-received by teachers, we tested the activities with a group of physics undergraduates as there were constraints to access schoolteachers because of the Covid-19 pandemic.

II. METHOD

This study was a developmental research using the ADDIE model to develop the activities. ADDIE model is a well-known model that is commonly used for designing effective teaching and learning activities [1]. The five phases in ADDIE model are Analysis, Design, Development, Implementation and Evaluation [11]. In this study, the research activities based on the ADDIE model are presented in Table 1.

Table 1. ADDIE Model

Step	Description
Analysis	• Analysis research objectives, research sample and scope of content • Determine the learning standards as documented in ACSD (MoE, 2018)
Design	• Design STEM-based activities for Pascal Principle using the 5E instructional model for planning the activities in each phase of the teaching and learning
Develop	• Develop activities and related T&L materials
Implement	• Administer the materials to determine perceptions toward the activities
Evaluate	• Content Validity of activities by experts • Students' perception of the activities

Two experts validated the activities for content validity. The population was 135 physics undergraduates in their fifth and seventh semester of study from one of the public universities in Malaysia. Data was collected using a questionnaire that was adapted from a standardised usability instrument [11] and was subsequently validated for face, content and reliability. It has four dimensions namely, content, language, activity and product designs, and interest. The questionnaire was distributed using Google Form to the population together with a link to the activities. The response rate was 29.6% (40 respondents). Data were analysed using descriptive statistics of percentage.

III. RESULTS AND DISCUSSION

Figure 1 shows a part of the activities in the 'Elaborate' phase where the engineering design process was planned. The 'Elaborate' phase is where learning is extended by having students apply their understanding that was gained from 'Explore' and 'Explain' phases in new contexts preferably related to the real-world. The activity starts with the teacher presenting a scenario that embeds a real-life problem for the students to solve by designing and developing a technology. The total duration of the lesson is 180 minutes in which 120 minutes are allocated for the 'Elaborate' phase.

Day 2 120 minutes **Elaborate**	**Engineering Design Process** Defining Problem • Introduce the problem through a problem scenario and let students identify the problem and its constraints. *Problem scenario: Rosa is a single mother and has three children who are still in school. She lives in a very busy and crowded city. Every morning she had to get up at 4 a.m. to get ready and prepare for her children's supplies before they go to school by van. Rosa needs to leave the house for work as early as 6:15 a.m. to prevent traffic congestion as the only road to her workplace will take her 45 minutes. However, there is a nearby river that if she can cross it, her travelling time to her workplace which is located in the next town can be cut down to only 15 minutes. Rosa would then have enough time for herself as well as have breakfast with her children. But, if a road were to be built to cross the river, ships that carrying cargo could no longer cross the river. So, if you are an engineer, what technology can be built to help the many city dwellers who are facing the*

	same problem as Rosa? • The constraints for building a prototype technology include using Popsicle sticks and a syringe as the main building materials. Research ▪ Form groups of 4 members each. ▪ Give worksheets to each group as a guide to perform group activities particularly the engineering design process. ▪ Students search for existing solutions. ▪ Students identify materials and tools that can be accessed to build a hydraulic drawbridge. ▪ Students identify the concepts of physics that can be applied in finding solutions.

Fig 1. A part of the activities in the 'Elaborate' phase

The activities explicitly integrate engineering design processes and engineering and science practices with Pascal Principle as the content of science. In addition, students use problem solving and simple arithmetic in designing and building a prototype of the hydraulic bridge and subsequently do some routine problem solving using the mathematical formulation related to the hydraulic system as a force multiplier. The hydraulic bridge is thus the technology that solve the problem as depicted in the scenario. The activities followed closely the definition of the STEM approach as proposed by [9]. In addition to being a solution to a problem, technology in this lesson is also used as an enabler for the learning process. The engineering design process [defining problem, research, imagine, plan, create prototype, test prototype, & improve [14] is explicitly outlined in a student worksheet and thus lets students experience the process systematically.

For content validity of the developed activities, two experts were 95.5% in agreement. Table 2 shows the result of the perception of the physics undergraduates towards the activities.

Table 2. The Percentage of Agreement for Every Dimension

Dimensions (No. of items)	Percentage of Agreement (%)
Content (N=10)	98.5
Language (N=5)	99.5
Design (N=5)	99.0
Interest (N=10)	96.3
Total (N=30)	98.3

In terms of interest, the respondents agree that the activities increase their interests in studying physics, improve their science process skills, solve problems related to Pascal Principle, and encourage them to think critically and innovatively. The respondents' perceptions are very much in line with many previous research that investigated the effect of the STEM approach on teaching and learning [3][12][13].

In addition, students' perceived positively the content, language, and the design of the activities with the total percentage of agreement of all constructs being 98.3%. This positive perception is aligned with experts' evaluation of the activities. Experts agree that the activities have integrated STEM elements, well-composed content, and use understandable language.

IV. CONCLUSION

We have succeeded in developing a validated lesson with activities based on the integrated STEM approach that was perceived positively by our respondents. Thus, the lesson ideas and materials can be used as a teaching and learning resources for teachers who are keen to implement lessons that integrate the four elements of the STEM approach. The materials may also give inspirations to teachers who may want to design their own integrated STEM lessons especially since the materials developed are in the form of lesson plan and student worksheet that clearly show teachers the way to design such lesson activities.

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