Inventive Problem-Solving in Project-Based Learning on Design and Technology: A Needs Analysis for Module Development

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https://doi.org/10.24191/ajue.v18i1.17196

Received: 30 November 2021
Accepted: 6 January 2022
Date Published Online: 31 January 2022
Published: 31 January 2022

Abstract: Education in Malaysia is transforming to increase students' ability and meet the needs of the industry. In Design and Technology subject, students apply the technology to develop a product capable of solving problems through a project-based learning approach. Therefore, this study aims to (a) identify problems in the implementation of design project and (b) identify the needs for module development. An online survey was conducted on 140 Design and Technology subject teachers in Batu Pahat district, Johor. Findings showed that the overall level of problem in the implementation of project-based learning was high and there was no significant difference in perception of problems in implementing project-based learning by gender, but a significant difference of perception by teaching experience. In terms of module content, the overall findings showed that the content requirement in the module was high. Gender and teaching experience showed no significant difference in perception of module content requirement. Finally, the findings showed that the suggested module design features are using Arial font and multi-colour, content in point form, A4 size, and contain graphical content. Therefore, it is proposed that this module should be developed due to its high requirements and should meet the needs of users, so that the goals of project implementation can be achieved.

Keywords: Design and technology, inventive problem solving, modules, project-based learning

1. Introduction

The direction of education in Malaysia is transforming facing the era of industrial revolution 4.0 (IR 4.0). Looking at the needs of IR 4.0, the role of education in shaping a new skilled generation in automation and the ability to develop high technology products should be emphasised (Ilias & Ladin, 2018). However, the quality of students produced is still far from meeting the requirements of IR 4.0 as students' knowledge of IR 4.0 is weak (Ismail et al., 2020). Graduates, especially in the engineering field, still do not master problem-solving skills. Mat Isa et al. (2021a) found that students were not able to develop solutions to complex problem solving and they need proper guidance from their lecturer. This shows higher dependence of students on their lecturers and they are unable to independently find solutions for a problem. Lecturers' participation in complex problem-solving training is also low compared to their years of service (Mat Isa et al. (2021b). This will actively affect students' problem-solving skills in higher education and the quality of graduates produced.

One of the causes leading to the dependency of students on lecturers to find solutions to complex problems at the university level is the lack of exposure to problem-solving skills at the school level (Derler et al., 2020). At school, students gain problem-solving skills through project-based lessons as they allow students to generate ideas and develop products using technology. Project-based learning can cultivate students to solve various problems as well as build creativity while improving soft skills (Faozi et al., 2020). Bridging project-based learning and problem-solving skills, the Design and Technology subject has become a good platform for lower secondary school students (13–15 years old) to build their skills (Sahaat & Mohamad Nasri, 2020). The subject is assessed through the development of products in each topic where the applications of technology need to be implemented. In addition, in terms of developing a product, inventive problem-solving skills should be applied to help students develop ideas and able to create innovations (Sai'en et al., 2017). Therefore, the content of the Design and Technology subject exposes students to inventive problem solving and technology applications such as manufacturing technology, mechanical design, electrical, electronics, aquaponics, fertigation and irrigation systems, fashion, food, and electromechatronics (Sahaat & Mohamad Nasri, 2020).

Project-based learning is a teaching strategy that involves the process of designing and showcasing products developed to solve problems (Abidin & Hariyono, 2020). During the planning process, students have to analyse the needs of product development, identify weaknesses of existing products, and make improvements on existing products based on inventive problem solving theory (TRIZ) (Ministry of Education, 2020). The impact on project-based learning enables students to build knowledge, skills, attitudes, as well as foster creativity in addition to train students to solve problems (Andanawarih et al., 2019; Song, 2018). However, the implementation of project-based learning is not as easy as conventional learning. Tee et al. (2020) found that project-based learning approach implemented in Design and Technology subject does not achieve the goal when students were not able to develop a product capable of solving problems because they could not express good ideas. In project planning stage, students faced problems of applying the concept of inventive problem solving which is important in developing a product. As a result, teachers have to describe the steps in inventive problem solving based on product designs chosen by the students.

In addition, time factor is a challenge to the implementation of project-based learning. The time spent becomes longer in implementing design projects when teachers have to explain in detail to each student according to their respective projects which are mostly different (Sahaat & Mohamad Nasri, 2020). Furthermore, the level of students' knowledge and skills is still low, and has become a constraint in project-based learning (Abidin & Hariyono, 2020). This is due to lack of students' exposure in project –based learning and problem solving. Besides, students are not able to apply the steps in solving inventive problems during the learning process and causing the tasks performed to be of poor quality (Che Wan Razak et al., 2020). Therefore, the application of inventive problem solving in project-based learning should be emphasized so that students are able to carry out the project in each chapter easily and also prepared the students with skill for higher education later.

The use of modules is an approach that is flexible and facilitates students to understand lesson content effectively whether with a teacher's guidance or self-learning (BPK, 2018). By using modules, learning can be carried out either independently by students or in the classroom with teachers (Yee et al., 2020). As a result, the use of modules can facilitate teachers to meet the varying needs of students without compromising the quality of teaching and save time (Nardo, 2017). According to Sarwandi et al. (2019), implementation of module has improves students' achievement in project-based learning. This actively demonstrate that modular approach can be applied in project-based learning. Sahaat and Mohamad Nasri (2020) also found that the teaching module of Design and Technology subject is seen as very important because it can help teachers to guide students in a shorter period. There have been issues incorporating inventive problem solving in project-based learning and the time constrain, thus, the use of modules seems to help teachers and students in project-based learning activities. Therefore, this study was conducted to identify the needs for the development of inventive problem solving module integrated with project-based learning in Design and Technology subject as well as identify problems in the implementation of design project.

2. Methodology

This study employed a quantitative design approach, using a survey to collect responses from respondents. The instrument consists of 4 sections, a) Demographics of respondents, b) Problems of implementing project-based learning, c) Requirements of Module Content, and d) Module design features. For Sections B and C, 5-point Likert scale was used (1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree). The instrument developed was reviewed by experts to determine the validity. A pilot study was conducted in two phases depending on the feedback provided by the pilot study respondents. For the initial phase, questionnaires were distributed to 30 teachers who did not participate in the actual study. An attachment form is included with the questionnaire to record teacher comments and suggestions. In addition, discussions with respondents were conducted to identify ambiguities and doubts on the meaning of the items. Next, items were analyzed to obtain Alpha Cronbach values. Then, a pilot study was conducted a second time to obtain a high reliability index. The results of the pilot study showed that the value of Alpha Cronbach is 0.905 for Section B, 0.818 for Section C and 0.835 for Section D.

Next, the collected data were analysed descriptively and inferentially. For the items in Sections B and C, mean values were interpreted according to Lendal (1997) into three levels based on Table 1.

Table 1. Interpretation of mean scores

Mean score	Min level
1.00 – 2.33	Low
2.34 – 3.67	Moderate
3.68 – 5.00	High

The study population consisted of Design and Technology subject teachers in Batu Pahat district, Johor. A total of 140 samples were selected using simple random sampling. Table 2 shows the demographics of the respondents involved in the study. From Table 1, respondents are dominated by female teachers (72.9%) compared to male teachers (27.1%). The majority of respondents have more than 10 years of teaching experience which comprises of 67.2% of the respondents. Furthermore, teachers who teach all levels in this subject dominate the demographic which is 30.0%.

Table 2. Respondent demographic characteristics (N=140)

Demographic Variables	Categories	Percentage (%)
Gender	Male	27.1
	Female	72.9
Teaching experience	0 to 5 years	8.6
	6 to 10 years	24.2
	11 to 15 years	34.3
	16 years and above	32.9
Teaching Class	Form 1 only	4.29
Form 1 (13 years old)	Form 2 only	8.57
Form 2 (14 years old	Form 3 only	15.71
Form 3 (15 years old)	Forms 1 and 2	27.14
	Forms 1 and 3	1.43
	Forms 2 and 3	12.86
	Forms 1, 2, and 3	30.00

3. Results and Discussion

3.1 Problems of Implementing Project-Based Learning

The analysis of problems in the project-based learning implementation is shown in Table 3. Overall, the level of problems in the implementation of project-based learning is high (m=4.00). This indicates that there are difficulties in carrying out design projects. The highest score shows that teachers need various examples related to inventive problem solving (m = 4.46) and teachers need modules to teach inventive problem solving skills in designing projects (m = 4.46). This finding is in line with Sahaat and Mohamad Nasri (2020) who state the need for learning modules. Next, students do not have specific skills to solve problems in project-based assignments (m = 4.10) followed by students have difficulties to identify the root cause of a problem to develop the product (m = 4.07). This finding is in line with Tee *et al*. (2020) who found that students are not able to master inventive problem solving, consisting of four phases namely identifying the root cause of the problem, modelling the problem, selecting problem solving tools, and modelling specific solutions. Furthermore, the teachers face moderate difficulties to explain the topic of inventive problem solving to the students (m = 3.66). These findings indicate that teachers have no problem in giving explanations to students.

Table 3. Problems of implementing project-based learning

No	Item	Min	Level
1	Students find difficulties to identify the root cause of a problem in developing a product.	4.07	High
2	Students do not have specific skills to solve problems in project-based assignments.	4.10	High
3	Students do not master the content of inventive problem- solving topics.	3.93	High
4	Students are unable to produce innovative products because they do not master inventive problem solving skills.	3.94	High
5	Students have difficulties to get high score in product development assignments.	3.71	High
6	Students do not have specific guidelines for solving problems inventively.	3.90	High
7	Teachers lack of experience in teaching inventive problem solving.	3.77	High
8	Teachers have difficulties to explain the topic of inventive problem solving to students.	3.66	Moderate
9	Teachers need a variety of examples related to inventive problem solving.	4.46	High
10	Teachers need modules to teach inventive problem-solving skills integrated with design projects.	4.46	High
	Overall	4.00	High

Table 4 shows the findings for the independent sample t-test. Levene's test shows the existence of similarity of variance for the cause of problem between two gender groups of teachers, F = 0.000 and p = 0.998 at the 0.05 significance level. The results show values of t = 1.970 and p = 0.051. The p value is above the significance level. Thus, it can be concluded that there is no significant difference for the perception of project implementation problems between male and female teachers.

Table 4. T-test results comparing male and female teachers' perceptions of problem in implementing project-based learning

	Gender	N	Mean	Std. Deviation	F	Levene sig	t	Sig (2-tailed)
Problems	Male	38	4.1579	.56694	.000	.998	1.970	.051
	Female	102	3.9412	.58299				

Table 5 shows the values of F = 5.398 and p = 0.002. The p value is less than the 0.05 significance level (p <0.05). The null hypothesis is rejected. Thus, it can be concluded that there are significant differences for the perception of problem in project implementation based on teachers' teaching experience.

Table 5. One-way ANOVA results comparing different teaching experience perceptions' of implementing project-based learning

		Sum of Squares	df	Mean Square	F	Sig.
Problems	Between Groups	5.057	3	1.686	5.398	.002
	Within Groups	42.463	136	.312		
	Total	47.520	139			

3.2 Requirements of Module Contents

Table 6 shows the content of the modules required by the teachers. Overall, all the contents stated show high requirements (m = 3.35). The findings show that the highest requirement is that the module has reinforcement activities at the end of the chapter (m = 4.43) followed by the need for examples of clear working steps in developing a product (m = 4.36). Next, the module must also have a visual description (4.34) and shows inventive problem solving steps in project implementation (m = 4.33) and contains a description of TRIZ (m = 4.29). Therefore, each component specified in the item should be taken into account in the module development process. According to Meyer (1988), reinforcement activity at the end of topic should be designed in a module to assess students achievement on the objectives of the topic.

Table 6. Requirements of Module Contents

No.	Items	Mean	Level
1	Contain a description of inventive problem-solving theory (TRIZ).	4.29	High
2	Contain inventive problem-solving steps in project production.	4.33	High
3	Have a visual description of inventive problem-solving in project implementation.	4.34	High
4	Have a clear example of work steps in developing a product.	4.36	High
5	Have a reinforcement activity at the end of the chapter.	4.43	High
	Overall	4.35	High

Table 7 shows the findings for the independent sample t-test. Levene's test shows the similarity of variance for the cause of problem between the two gender groups of teachers, F = 2.184 and p = 0.142 at 0.05 significance level. The results show values of t = -1.111 and p = 0.912. The p value is above the significance level. Thus, it can be concluded that there is no significant difference in module content requirements between male and female teachers.

Table 7. T-test results comparing male and female teachers' perceptions of module content requirement

	Gender	N	Mean	Std. Deviation	Test F	Levene sig	t	Sig (2-tailed)
Module Content	Male	38	4.3368	.89697	2.184	.142	-.111	.912
	Female	102	4.3529	.70482				

Table 8 shows the values of F = 1.524 and p = 0.211. The p value is above the significance level of 0.05 (p> 0.05). Thus, it can be concluded that there is no significant difference for the perception of module content needs based on teachers' teaching experience.

Table 8. One-way ANOVA results comparing different teaching experience perceptions of module content requirement

		Sum of Squares	df	Mean Square	F	Sig.
Module Content	Between Groups	2.600	3	.867	1.524	.211
	Within Groups	77.350	136	.569		
	Total	79.950	139			

3.3 Module Design Features

Table 9 shows the module design features required by the respondents. A total of 58.6% of respondents choose the Arial font, while 41.4% of the respondents choose the Times New Roman font. In terms of the use of colour, a majority of respondents choose multi-coloured writing (94.3%) compared to writing that consists of only one colour (5.7%). Furthermore, in terms of the form of description, 95.7% of the respondents choose point-form description, while only 4.3% of the respondents do not choose the point-form description. In terms of content, 97.1% of respondents choose graphic content compared to 2.9% who choose non-graphic content. Next, most respondents choose A4 size (90.0%) over A5 (5.7%) and B5 (4.3%). Therefore, in the production of the module, the characteristics of the respondent's choice will be taken into account to facilitate users to use the module more effectively.

Table 9. Module design features

No.	Features	Criterion	Percentage (%)
1	Font types	Times New Roman	41.4
		Arial	58.6
2	Multi-coloured fonts	Yes	94.3
		No	5.7
3	Description in point form	Yes	95.7
		No	4.3
4	Graphical content	Yes	97.1
		No	2.9
5	Module size	A4	90.0
		A5	5.7
		B5	4.3

4. Conclusion

This study has determined the need for the development of an inventive problem-solving module integrated with project-based learning in addition to identifying the problems faced by teachers in the implementation of project-based learning in the Design and Technology subject. Findings show a high level of problems in the implementation of project-based learning in Design and Technology including the difficulty in mastering the phases in inventive problem solving resulting in students' ability to produce innovative products and getting good scores in project implementation. Therefore, the implications of this study allow quality modules to be developed in facilitating teachers to guide students more effectively. With modules that integrate inventive problem solving and project-based learning, students can apply the concept of inventive problem solving to produce quality and high technology products at the school level. Besides, this study implies higher education whereas students are exposed to project-based learning and problem-solving at the school level which will make them solve a problem independently with skills cultivated at school and can be applied in integrated design subjects and final year projects at university. In the end, students can graduate with the required skills and be able to serve with maximum capacity in the industry.

5. Suggestion for Future Research

Since this study had only focus on teachers in Batu Pahat district. It is recommended that further research be carried out on teachers from other districts to see whether there are any similarities in the findings. Furthermore, further research could also design and develop module of inventive problem solving intergrated with project-based learning. Lastly, further study on the effectiveness of inventive problem solving on project-based learning can be carried out.

6. Co-Author Contribution

Author1 and Author2 carried out the field work, prepared the literature review and overlook the writeup of the whole article. Author3 wrote the research methodology and did the data entry. Author 4 and Author5 carried out the statistical analysis and interpretation of the results. All authors discussed the results and contributed to the final manuscript.

7. Acknowledgements

We wish to thank the Ministry of Higher Education Malaysia for funding this study under the Research Excellent Consortium Grant Scheme (KKP) or KPM-Special Grant RMK-10 (JPT(BPKI)1000/016/018/25(64). The authors also would like to extend their gratitude to The Registrar Office Universiti Tun Hussein Onn Malaysia for sponsoring this research. Thanks also go to all who participated in this study.

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