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Determining the Elements of Problem Solving Strategies in Project-Based Laboratory (PB Lab) Course*

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This study focuses on determining the elements of problem solving strategies that occur during Project-based Laboratory (PB Lab) teaching and learning (T&L) activities. Problem solving strategies are defined as strategies which significantly relate to the elements involved in problem solving procedures that guide students to solve problems during T&L activities. Four groups, each of which consists of five students and one PB Lab facilitator, were observed. Seven PB Lab facilitators were interviewed. The respondents are from the Bachelor of Electrical Engineering (Power) (SEE) program in the Faculty of Electrical Engineering, Universiti Teknologi Malaysia. This qualitative research employed the thematic analysis technique in determining the themes related to the elements of problem solving strategies that occurred during the PB Lab activities. The results of the analysis have indicated that there are five main processes associated with the problem solving elements that took place during the PB Lab course activities, which led to enhancing the students' problem solving skills in the laboratory context.

Keywords: problem solving startegies; problem solving process; teaching and learning (T&L); project-based laboratory (PB Lab)

1. Teaching and learning (T&L) approach in developing students' problem solving skills

Nowadays, the teaching and learning (T&L) approach has undergone a great transformation from being passive lecture-centered to becoming active student-centered. This transformation has had a great impact on the students' learning, especially for engineering graduates. Generally, teaching is defined as a matter that involves transmitting knowledge, while learning involves receiving the knowledge accurately, storing it, and then applying it appropriately [1]. This view of T&L shows that both elements are related to each other, which is in line with a quote by Albert Einstein in the article produced by [2]:

> "I do not teach anyone, I only provide the environment in which they can learn"

The relevance of the quote above to this very day is very much evident when various T&L strategies are promoted and implemented. Einstein's quote underscores the responsibility of the educators to implement a learning environment that leads students to achieve the required outcomes. Bringing this concept into the engineering education context, it is noted that the previous traditional educational approaches that focus more on content knowledge are insufficient to produce multidisciplinary engineering graduates. For this reason, many initiatives have been conducted among engineering education researchers in order to ensure engineering graduates are able to produce the outcomes demanded by industries. Among the crucial outcomes that all engineering graduates need is problem solving skills. A few years ago, [3] has stressed the lack of problem solving skills among engineering students, especially in their ability to solve real-world issues, even though they have solved more than 2,500 problems during their undergraduate studies. Later in 2004, the issues have been discussed again by [4] Chair of the Committee on the Engineer of 2020, which highlighted the need of future engineers to quickly prepare themselves with the new knowledge, and the ability to apply this knowledge to emerging real-world problems. Based on the aforementioned facts, the importance of problem solving skills nowadays are determined to be crucial, especially for future engineers. Besides, the need of problem solving skills is a requirement by the Accreditation Board for Engineering and Technology [5]. In its program outcome (PO5), it has stated that engineering graduates must be able to "identify, formulate and solve engineering problems" before they graduate. Shortly, it can be summarized that problem solving is still the most required outcome that most of the engineering graduates lack [6, 7].

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Such consistent prominence has shown an amount of studies in the body of literature on various teaching and learning approaches in Engineering Education (EE) across various engineering areas around the world. Specifically, the transformation of T&L in EE took place after Outcome-based Education (OBE) was promoted by ABET when it was first introduced in 1997. OBE is an educational restructuring model which has been recognized and supported by many accreditation boards and institutions [8, 9]. This is a "bottom up" approach, where the outcomes that students should achieve after graduating become a guideline in organizing the curriculum, teaching, as well as learning instructions and types of assessment [10, 11]. Hence, in the context of T&L instructions, non-traditional T&L approaches have been promoted and recognized [12]. These active T&L approaches are in line with the OBE's visions, where the focus is on the outcomes of student-centred learning. The active T&L approach is similar to instructional strategies that require students to be involved in the learning activities so that they will be able to think, decide and solve problems independently [13]. The lecturers' responsibilities during active T&L are more focused on enhancing, facilitating, and asking questions that lead students to think critically. Through the active T&L approach, lecturers facilitate the students to actively engage during the learning process, and participate in exercises and discussions, which may lead them to be good problem solvers [14]. This approach is important to students, since they can control their own learning, and determine whether they possess certain knowledge. In short, it can be noted that the main characteristic of active learning is engaging students in learning activities so that they do not passively learn and intake knowledge. Besides, in terms of teaching, teaching styles are other elements that are of importance to active T&L strategies. Instead of teaching that promotes students to memorize, the questioning technique is another effective teaching style that encourages students to think in order to solve the problem at hand. Generally, lecturers can guide students by asking critical questions that lead the students to think, e.g., a) Why do you think that?; b) What is your related knowledge?; and c) How do you view it? [15]. According to [16], asking suitable questions to students may help to stimulate their thinking skills; hence they will start 'thinking about their thinking'.

Many studies [17–19] have shown that active T&L approaches have been used extensively in the EE domain, and the more famous ones in EE are project-based, problem-based and case-based approaches [20]. According to [21], each of these active learning approaches has its own learning principle in guiding the students to learn and solve problems independently instead of only receiving all the information from the lecturer. In a study by [22] it was reported that the students were more confident in problem solving, and were able to solve challenging problems after they went through class lessons that used the Problem-based Learning (PBL) approach. Besides, [23] also examined the PBL approach applied in an electrical engineering programme in the UK; the results revealed that the students preferred the PBL teaching and learning approach because it enabled them to develop their thinking and problem-solving skills. Another study by [24] found that the students were really interested in Project-based Learning because they felt that their problem-solving skills improved upon completion of the project. Investigations by [25, 26] reported that students were more confident in solving problems, and were willing to solve challenging problems after they went through the class lessons that used active T&L strategies. In fact, more new T&L approaches are being developed globally in ensuring the students' problem solving skills are improved.

Within the Malaysian context, a number of academics have begun initiatives in seeking the appropriate T&L approach in enhancing the problem solving skills among Malaysian engineering graduates. The [27] listed four out of eleven program outcomes (PO) in its Engineering Programme Accreditation Manual that are related to the problem solving. Some of the related EAC's outcomes in PO1 were:

> Students of an engineering programme are expected to attain the following: Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.
>
> (Engineering Accreditation Council, 2012:3)

The EAC's aforementioned outcomes in fact relate to the demand made by the Malaysian Qualifications Agency [28], which stated that "the training of future engineers, engineering technologists and technicians must focus on solving both common and complex problems". These show the need of more effective T&L approaches that can provide students with the learning environment necessary to lead and train them according to the industry and engineering accreditation needs. In 2005, [29] implemented the "project-based" approach in the fourth year laboratory (PB Lab) course for final year students at the Faculty of Electrical Engineering. Based on these studies [30, 31], there were many positive comments from the lecturers and students after they gone through this lab. Instead of conducting the laboratory based on a conventional approach, this "project-based" active

T&L approach provided the students the opportunity to develop their own procedures and techniques to tackle the problems given. In addition, as [32] has also explored the uniqueness of the active T&L approach by implementing "problem-based learning (PBL)" in her Process Dynamic and Control Course at the Chemical Engineering Faculty, and the outcomes was highly successful. Other researchers soon followed these particular T&L trends by adopting the PBL in their teaching instruction [33, 34]. Through the results of the learning outcomes, the effectiveness of the PBL T&L approach they have implemented can be seen based on the positive feedback from the students. Until recently, research that is related to the effectiveness of the T&L approach in developing students' problem solving skills is still on-going.

However, it is surprising that even after significant changes in T&L approaches used by EE educators, lately; there are still many complaints from industry leaders concerning the lack of skills among graduates, especially in solving problem in the workplace [35, 36]. The concern over this issue has constantly been the main focus by most of the researchers in EE. To explore these issues, many researchers examined their T&L effectiveness in enhancing students' problem solving skills; however, less work has been done in reviewing their T&L approach, and whether it has truly been conducted by providing a correct learning environment that leads students to solve problems. It is important, because problem solving, based on the perspective of cognitive constructivism theories, claims that students create meaning in their mind by interacting with other people and the surrounding environment. This situation implies that the environment of the T&L approach must be reviewed in order to ensure proper a learning environment is provided for students. For this reason, one of the strategies that can create and promote proper learning environments for students in enhancing their problem solving skills is by implemented in T&L the approach [37, 38].

2. Problem solving strategies in teaching & learning (T&L)

> "I understand the concept. I just can't do the problems."

Generally, many students always mentioned issues similar to the above dialogue. They mentioned that they know the concept or formula behind the problem, but are still unable to solve it. If the concept they mention is true and correct, but they still do not know how to solve it, then maybe they are lacking on the problem solving strategies in order to solve it. Problem solving strategies, as defined by [38] are among the strategies that can enhance the effectiveness of T&L, especially when applied experientially, and are strategies are like a route or process that guide students to solve problems, and do not only focus on the correctness of the final results. The process which described in these problem solving strategies is a problem solving process [37].

Specifically, problem solving is a "process" of thinking that is applied by people in order to solve problems with unclear final solutions [39–41]. It can also be defined as a cognitive process that requires the mind to select activities and systematically work for them [42]. Defined as a process, problem solving has been divided into a number of stages by many researchers. There are four, five and six problem solving step-by-step processes have been proposed and implemented (39, 43, 44). Each of these processes has been implemented and used based on its relevance in different domains. Starting from the early steps of problem solving, such as identifying the problem until coming up with the possible solutions and evaluating them, these processes are included in the problem solving strategies that can guide students' thinking in solving problems [45]. According to [46], the implementation of these problem solving strategies in T&L are proven to be among the elements that require students to be involved with problem solving procedures, and this can improve students' problem solving skills. Some of the activities include problem solving strategies in their T&L, e.g., creating activities that require students to describe the problem solving process that they went through, and then find solutions to the problems [45]. This kind of activity guides the students' thinking so that they have the framework of problem solving in their mind, which can be applied anytime when solving other problems [47].

According to [9], there are some factors which have been recognized to influence the development of problem solving skills among students, such as the inability to interpret a given problem, the inability to understand the problem, and lastly, the lack of knowledge on how to implement problem solving strategies in solving problems. These factors are related to the need of implementation of problem solving strategies during the T&L process. Most students are given open-ended and real problems to solve, but they are not trained for the processes that they must go through so that they can successfully solve the problem. Based on [48], problem solving skills among students can be enhanced by providing them with the appropriate learning activities that incorporate problem solving strategies. The problem solving strategies or processes which are included in learning activities also help students to identify their weaknesses in solving problems [37]. Hence, this statement clearly mentions that it is important to focus, not only on how to implement learning activities, but also on the problem solving processes that can help to develop students' problem solving skills. There are various techniques in incorporating problem solving strategies in T&L activities so that students' problem solving skills can be well developed [49]. Some of the T&L activities that include problem solving strategies are [45]:

(a) Give the students the problems that they have to solve, and at the same time, provide them with a problem-solving step-by-step framework which can guide their thinking.
(b) Teach students about the benefits of problem solving by giving them real world problems.
(c) Facilitate students in creating the solution plan by encouraging them to discuss among members so that they can think in different ways to solve the problem.
(d) Give examples of an open-ended problem with several solutions in order to change the students' thinking perspectives that there are multiple ways to solve the problem at hand.
(e) Ask students to reflect in writing what they have done, what they have achieved and where they struggled.

Generally, there are other examples of T&L activities that include the problem solving process as their problem solving strategies. It is important to guide and facilitate students with the problem solving processes in their learning activities so that their thinking process is guided, and this enables them to avoid the factors that might hinder their problem solving skills. There are numerous studies [50, 51] that discuss the effectiveness of problem solving strategies in T&L for improving students' problem solving skills. However, less work has been done on reviewing whether the element of problem solving strategies, i.e., the problem solving process, is truly included in their T&L activities, so that each of the students can naturally develop their own problem solving skills after they go through the process.

3. Overview of project-based laboratory (PB Lab) course

The PB Lab course is a 4th year laboratory course that starts with a "project" as an approach in developing students' thinking and skills in a laboratory setting [29]. It has successfully been implemented as part of the Bachelor of Engineering (Electrical) program curriculum at the Faculty of Electrical Engineering (FKE). The aim of the PB Lab is to induce several changes in the laboratory context to transform it from a teacher-centered approach to a student-centered approach, mainly by introducing real-world (or close to real-world) problems presented in a form of projects to be solved in a group. Specifically, there are three undergraduate programs offered under the FKE, which are Bachelor of Engineering (Electrical) (SKEE), Bachelor of Engineering (Electrical-Electronics) (SKEL) and Bachelor of Engineering (Electrical-Mechatronics) (SKEM). However, in this study, only the SKEE program is considered. In addition, realizing the outcomes as among the important points that are evaluated, the FKE has taken conditional steps to determine the required outcomes for each of the programs and courses conducted. Table 1 shows the course outcomes of this PB Lab course as listed by the faculty.

Based on the PB Lab course outcomes listed above, problem solving skills are among the prominent skills that are crucial for a student to possess at the end of the course. Course outcome CO1 and CO2 of this PB Lab COs clearly state a criterion of problem solving skills. Students must able to "identify, formulate, investigate and synthesize information to solve complex engineering problems independently by relating theories and concepts discussed in lectures and information obtained from other learning resources", as well as "use appropriate techniques, skills, modern engineering tools, instrumentation, software and hardware

Table 1. PB Lab Course Outcomes

No.	Course Outcomes (CO)
CO1	Identify, formulate, investigate and synthesize information to solve complex engineering problems independently by relating theories and concepts discussed in lectures and information obtained from other learning resources.
CO2	Use appropriate techniques, skills, modern engineering tools, instrumentation, software and hardware necessary for solving complex engineering problems with an understanding of their limitations.
CO3	Conduct experiments and research, perform analysis and interpret data for complex engineering problems.
CO4	Plan and conduct a project within a specified budget and time frame using available resources for complex engineering problems.
CO5	Design solutions for complex systems, components, or processes with appropriate consideration for public health and safety, legal and cultural issues, and environmental consideration.
CO6	Function effectively as an individual, and as a member or leader, in diverse teams.

necessary for solving complex engineering problems with an understanding of their limitations''. Both of these PB Lab course outcomes are related to problem solving skills, as they stress the need of students to be able to solve complex engineering problems based on the knowledge and practical skills they possess. These outcomes are aligned with the outcomes of the Engineering Accreditation Council (EAC), which requires students to have complex problem solving skills. Students in the PB Lab are given projects to solve within a given time period, while the role of the lecturers changes to facilitators whose main responsibility is to facilitate the students in moving forward towards solving the given projects, rather than directly informing students what to do. In contrast to the previous conventional laboratory, the PB Lab requires students to develop their own experimental procedures prior to conducting them as part of the project solution. This requires the ability of the students, not only to relate their prior learnt knowledge to the given project, but also to be engaged in discovery or exploratory learning.

Specifically, students are required to complete a given project as offered by each of the laboratories in a period of four weeks throughout the semester. Furthermore, the time allocated for the PB Lab is basically three hours per week inside the laboratory, involving the facilitators, and at least 24 hours per week outside the laboratory, involving only the students in their respective groups. Generally, the students are divided into groups of three to four.

3.1 PB Lab learning activities

Generally, the activities that are typically carried out in a PB Lab from week one until week four are shown in Table 2. The projects are designed by experts, whom in this case are experienced lecturers. Based on the given project, students are required to brainstorm for ideas, engage in discussions, and express their opinions on the probable solutions to the problem at hand. This is considered a challenging learning process for the students, as they have to develop a deep understanding on the subject matter to establish the suitable methods that can be applied in order to solve the problems related to the given project. To accelerate this process, a *Student Pack* is made available for each given project [29]. A *Student Pack* consists of relevant materials that are beneficial to the students in solving the problems related to the project. The students are able to download the *Student Pack* from the respective laboratory's website after they have presented the results of their preliminary discussion to the facilitator in charge. In addition, the *Facilitator Pack* [29] is prepared for each project and given to the PB Lab facilitators who in are charge of the lab. This is necessary because not all project designers will become facilitators. Thus, the *Facilitator Pack* is a tool for facilitators to refer to which basically describes the probable solution or the details of the project.

To gain more understanding about the PB Lab learning activities that have been implemented, Table 2 shows the process of solving the PB Lab problem, starting from week one, until week four. Therefore, in incorporating the problem solving strategies in the PB Lab teaching and learning approach, during the first week of the PB Lab course, an open-ended problem which has several solutions has been given to students to be solved. This ''open-ended problem'' strategy has been recognised as one of the elements that can promote the problem solving strategies in the PB Lab learning activities. Besides, in the PB Lab course itself, several discussion sessions took place among students and facilitators, starting from the first week, until the fourth week of PB Lab course. Students started to read and define the problem statement based on the problem given by engaging in discussions with their group members and their facilitators. This process has been determined as another way in ensuring the problem solving process that took place during the learning process based on [52]. According to the learning perspectives, students understand more the problems after they interact with other people surrounding them [52]. When the students carry out discussions with their group members regarding the problem issues, strategies to solve the problems and analyse the results are obtained, and their minds start to critically think and create meaning based on the information that they acquired from the interactions. This process leads the students to become good problem identifiers and problem solvers. Instead of that, as mentioned in the first paragraph of this section, the Student's Pack consists of general information about the project given such as the problem issues, the time frame of the PB Lab process, and the list of possible hardware and software tools that might help the students to plan the solutions. By giving this instructional material to the students, they can also independently construct their own ideas and plans, and hence do not have to directly follow the lecturer's thoughts [53].

Based on activities planned in the PB Lab course, as mentioned above, it can be seen that there might be problem solving strategies in its T&L activities. This is due to its structure, which exposes students to activities that involve problem solving and active learning in a team. However, no studies or initiatives have been done in reviewing back this PB Lab T&L structure in order to identify whether there are problem solving strategies in its teaching and learn-

Table 2. The PB Lab activities from Week 1 until Week 4#

Weeks	In-Lab session (3 hours)	Out-Lab session (2 hours)
Week 1	1. Understanding the project* with guide of facilitator. 2. Brainstorming; giving ideas to solve problems related to the project. 3. Identifying available resources and tools. 4. Identifying what is known and what is needed to be known in solving the problems related to the project. 5. Facilitator marks individual in-lab activities.	1. Get more resources to help understand the problems related to the project. 2. Divide work among group members. 3. Report findings to group. 4. Agree on a solution.
Week 2	1. Present solutions to facilitator. 2. Facilitator comments on solutions, making sure the group is on the right track. 3. Group begins to design the experiment. 4. Group confirms the experiment layout. 5. Facilitator monitors and marks individual in-lab activities and log books.	1. Group conducts some simulation work to reconfirm design. 2. Group verifies the availability of equipment and tools to conduct experiments. 3. Group prepares schematic or connection diagrams for experiment.
Week 3	1. Group begins to conduct experiment. 2. Facilitator monitors and marks individual-in lab activities and group log books. 3. Group obtains results from experimental work.	1. Group prepares slides for presentation of completed work. 2. Group starts preparing report.
Week 4	1. Group presentation and demo. 2. Report writing. (Facilitator monitors and marks individual-in-lab activities and group log books. Facilitators also evaluate all group presentations).	1. Continuation of report writing and submission exactly a week later to the Lab technician to be recorded and given to facilitators.

* Each group will be assigned one project.

ing design. Therefore, a qualitative study was employed to explore the element of problem solving strategies, which is the problem solving process, that took place during the Project-based Laboratory (PB Lab) T&L activities in details.

4. Research objective and research question

As highlighted above, it is important to ensure the problem solving strategies are included during the T&L activities. In this study, the extent that the PB Lab course nurtures students' problem solving skills with the element of problem solving strategies in its T&L approach is still vague. Therefore, the main objective of this study is to identify the elements of problem solving strategies which might occur in the PB Lab course T&L approach that help to improve students' problem solving skills. Specifically, this study attempts to answer the following question:

Research question:

"What are the elements of problem solving strategies that have occurred in the PB Lab course T&L approach?"

5. Research methodology

5.1 Participants

In order to answer the research question, four groups of students (groups A, B, C and D) were formulated, each of which consists of five students and one PB Lab facilitator. All groups were observed by the researcher for the four weeks of the PB Lab course (from week one until week four). All of the participants involved are students and lecturers from the Bachelor of Engineering (Electrical) or SEE program. The observation process for groups A, B, C and D was conducted from November until December, 2012, in two of the PB Labs, namely, the Advance Power Laboratory (APL) and the Power Electronic Laboratory (PEL). Specifically, the APL and PEL PB Labs are under the Bachelor of Electrical Engineering (Power) (SEE) program. In addition, seven PB Lab facilitators (P1, P2, P3, P4, P5, P6, and P7) from various electrical engineering fields were also interviewed. The interview sessions for P1 and P2 were conducted on December, 2012. The interview sessions for P3, P4, P5, P6, and P7 were conducted on November, 2013. The facilitators' responses toward how they conducted the PB Lab course from week one until week four were identified. Moreover, the PB Labs and the participants involved in this observation data collection have been selected based on purposeful sampling, which has been proven to be the most suitable sampling method for qualitative studies [54].

5.2 Settings

The investigation was conducted in the PB Lab course at the Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM). There are 17 laboratories from eight different programmes (including SEE) that are used during the PB Lab

4th year undergraduate laboratory course. However, this study only focuses on the students and PB Lab facilitators in the SEE programme, which is part of the Advanced Power, Power Electronic and High Voltage laboratories [29].

5.3 Data collection and data analysis

This study utilizes a qualitative research approach, and uses observations and semi-structured interviews to collect and analyze the data.

5.3.1 Unstructured observation

Observation is one of the main data collection methods which has been used in this study. This method has been utilized by numerous researchers in order to interpret the behaviors, attitudes, facial expressions and other non-verbal indications of some activities [55, 56]. Thus, in this study, the observation methods provide rich information in order to identify and gain insight concerning the problem solving process that took place in the PB Lab course by observing the students' activities. For this study, the unstructured observation method was chosen, since it allows the observer to closely monitor the students' activities carried out in the actual PB Lab setting with an open-ended view, rather than limiting the observation to only a certain area. Besides, in order to ensure the observation data are recorded effectively, "field notes" and some "video recording" have also been implemented.

Specifically, the researcher has thoroughly observed and recorded the PB Lab activities for three hours for each lab. The PB Lab course under the Bachelor of Engineering (Electrical) (SKEE) program has been chosen to be observed by researcher, because it is the main program in FKE. The observation was carried out throughout the entire duration of the PB Lab course (four weeks). This observation process provided the researcher with an overview to deeply understand the process of the PB Lab activities, as well as the participants' attributes towards the PB Lab activities related to problem solving. According to [57], the observation strategy is useful when the researcher attempts to understand and determine the behavior progress and process, as well as unfolding events. This statement supports the use of observation methods in this study, where the process of problem solving in the PB Lab course was the main objective to be identified and analyzed.

5.3.2 Semi-structured interviews

Next, in order to support the observation data, the face-to-face interview session was carried out in order to verify the observed problem solving process that took place in the PB Lab course. A semi-structured interview which involves a series of open-ended questions was implemented based on the research objectives. This open-ended questions strategy provides opportunities for both the interviewer and the participants to discuss a topic in detail, and results in the collection of rich data [58]. Therefore, in order to determine the facilitators' feedback, which may answer the research objectives, the following questions have been asked during the interview sessions.

> "How do you conduct the PB Lab course from week one until week four?"

Specifically, based on the above main interview question, the objective of this interview session is to determine the manner in which the PB Lab facilitators conduct the PB Lab course. Based on this information, the elements of the problem solving process which occurred during the facilitation activities can be identified.

5.3.3 Thematic analysis

Generally, the observation and interview data have been analysed in answering the research questions. By using the thematic analysis technique, the researcher was able to analyse the data by determining the explicit words or phrases, and focusing on identifying the theme of the data. Thematic analysis is a qualitative method implemented to analyse and report the theme of qualitative data [59]. In this research, data from both observations and interviews was gathered and separately analysed using thematic analysis, prior to being triangulated. Moreover, the six steps of thematic analysis given by [60, 61] were adopted as a guideline in this study.

By applying thematic analysis in this study, the written observation field notes and interview transcriptions were read and reread by the researcher. This process helped the researcher to manually determine the code in the data that was related to the problem solving process. According to [62], researchers who transcribe qualitative data on their own find it easier to familiarise themselves with the keywords used by the participants, which is important for data analysis. The determined codes were connected to each other in order to develop themes and patterns from the data collected.

Besides that, in order to guide the researcher to analyze only the data related to problem solving, the theory-driven strategy was been used. This strategy is a deductive means in which the analysis made by the researcher is based on certain theories or concepts [63]. Specifically, in this study, the Dewey's problem solving model [39] was chosen to be used as a guideline in analyzing the qualitative data of this research.

This model has been chosen due to its generality and practicality, which can be applied in many domains. According to several researchers [64, 45], this five-step model has been used by many cognitive psychologists and scientists who have agreed that problem solving is a "process" of thinking. The concept of problem solving used in Dewey's model highlighted that "problem solving is a process of thinking", and this is in agreement with the definition of problem solving by [40,41]. As stated below, there are five steps in the problem solving process in Dewey's model, which are as follows:

(i) Identify the problem.
(ii) Represent the problem.
(iii) Select the strategy.
(iv) Implement the strategy.
(v) Evaluate the results.

6. Results and finding

This section presents the results and findings obtained from this study. The elements of the problem solving process that have been identified based on observation and interview data were thoroughly discussed. The Dewey's step-by-step problem solving process has been used as a guideline during this data analysis. For convenience, the results and the discussion sections are divided into four parts, each of which is based on the four weeks of the PB Lab course.

6.1 Problem-based laboratory (PB Lab) week one (W1)

As highlighted, the discussion of the data analysis was divided into four parts, which is based on (a) week one, (b) week two, (c) week three, and (d) week four. Generally, based on the observation data in week one, there are several processes that occurred during these two different PB Lab courses from week one until week four. Besides that, it can be seen that the processes or activities that took place between APL and PEL PB Labs were mostly same, although the project given to the students were different. The same processes are clearly apparent at the beginning of two different PB Lab (APL and PEL) courses in week one, where the students were informed of the project that they had to solve by the facilitators. This was followed by a short introduction about the assigned project, PB Lab assessment information, and the PB Lab time frame for the projects. Specifically, the observation shows that all groups in APL and PEL PB Labs began to identify the main issues and objective associated with the problem given. According to [39], the first steps in the problem solving model consist of the problem identification. This is the most important step because students will read the problem given, and try to interpret and restate it back in their own words. The following are several excerpts taken from the observation data which shows the process.

It can be seen that student still can't understand what they need to do with the problem, so they go to the computer lab and ***find information*** *from the* ***internet*** *regarding the problem given. After an hour, this group comes back to the lab and starts a* ***discussion*** *with their group mates about what information they obtained.*

(Observation W1 Group A)

The facilitator ***asks*** *the students whether they have obtained any information related to the problem, and asks them about their understanding on the problem given, one student at a time.*

(Observation W1 Group B)

Some students ***brought books*** *and* ***read articles from e-journals*** *stored in their laptops to study the problem.*

(Observation W1 Group D)

The facilitator ***briefs*** *the students about the* ***concept of Unipolar and Bipolar electrical circuits****. Then the facilitators let the students* ***discuss*** *among their group members whether or not the concept can be applied to the problem given.*

(Observation W1 Group D)

The above excerpts clearly show that the activities in the PB Lab focused on problem identification during week one. It can be seen that there were several activities which lead and supported the students to successfully understand and identify the problem at hand, which are: (a) finding information from various sources such as the internet, books and journals; (b) engaging in question and answer sessions with the facilitators regarding the problem (c); engaging in discussions with the team members; and (d) applying the electrical fundamental knowledge that they have learned to solve the problem. According to [65], the activities of gathering or defining information about the problem from various materials, as well as talking to people who are familiar with the problem, will lead students to really understand the problem given. Thus, this is strong evidence that the problem identification process took place during the first week of the PB Lab course.

Moreover, based on the interview session with seven PB Lab facilitators (F1, F2, F4, F5, F6, and F7), the first problem solving process highlighted by them was also related to the problem identification. During the first week of the PB Lab course, the facilitators gave the students the problem that they have to solve, and informed them to discuss this problem in their team before coming up with the problem statement. For example, the following extraction was taken from F1:

"On the first PB Lab meeting, they will ***try to understand the problem*** *and* ***identify the problem statement*** *in order to better understand the problem. Then, I will give a short brief to the students about what will be assessed in this PB Lab course...... At the end of the first PB Lab session, I will* ***revise again what they understand about the problem***

and facilitate what they have done and their progress in week one."

(Participant F1)

The explanation was also similar to what was addressed by F2:

"During the first PB Lab meeting, I will provide the problem to the students, and based on that particular problem, they have to ***determine the problem objective****. Normally, I will provide 15 minutes to 30 minutes for them to think and* ***search on how to solve the problem****. After that, I will come to them and ask* ***what they understand about the problem****. . . . If they have learned the fundamental knowledge about the problem, I will advise them to* ***revise the topic*** *in order to help them to understand the problem."*

(Participant F2)

"On week one, students will ***obtain a problem*** *to solve. Then they* ***brainstorm*** *it and* ***search the related information*** *about it from the internet. They will* ***identify the related journal paper****".*

(Participant F5)

The above quotations indicate the facilitators' feedback on how the activities in the PB Lab course were conducted during week one. Generally, it can be observed that the "understanding of the problem" phase was discovered during week one. Students, with the facilitation of the facilitators, identified the problem statement and the objectives of the problem. There are several activities or processes mentioned by the facilitators that took place in the PB Lab, which led the students to understand the problem. These processes were: (a) revising the previous topic; (b) brainstorming and (c) searching for information about the problem. These activities helped students to deeply understand the given problem.

Overall, based on the triangulation of the observation and interview data for week one, it can be summarized that problem identification was the main process that took place during week one. Besides that, using the qualitative methods helped the researcher to identify other students' activities, which led them to further understand the given problem.

6.2 Problem-based laboratory (PB Lab) week two (W2)

Based on the observation data for week two, it can be observed that the main activities related to the problem solving process that took place in the PB Lab course were used. The students started to plan the procedures or strategies to be used to solve the problem. Generally, the students started the PB Lab course on week two by **identifying the relevant information** from various sources that can guide them to develop procedures or steps to solve the project. The examples of the activities taken from observation data are as follows:

Student sat in the respective group. They seemed to understand some ***references*** *that they are using. Three students brought* ***laptops*** *while the rest read and wrote something on paper. Most of them are reading* ***journal*** *on their laptops.*

(Observation W2 Group C)

The facilitator ***asked*** *the students on what they have found. One student showed the* ***simulation*** *that they have done. While the student demonstrated the simulation, the facilitators kept* ***asking*** *the students:* ***"What's next?"***

(Observation W2 Group C)

The facilitator ***asked*** *the students some* ***electrical fundamental knowledge****. Two students answered the question. Then the facilitator asked them to explain* ***how they apply the formula.***

(Observation W2 Group C)

Three students were designing the circuit. One student ***drew the circuit*** *while others were discussing.*

(Observation W2 Group D)

Three students tried to ***draw the circuit connection*** *on paper and tried to match it with the circuit on the trainer.*

(Observation W2 Group B)

According to [64, 65], planning strategies is one of the most important parts of problem solving. The students should spend more time planning the solution, as well as ask triggering questions which can develop the ideas. Some example questions are: *What do you want? How can you obtain this kind of thing?*, *How can you find this kind of unknown?*, and *From what data can you derive this kind of unknown?* [44]. Besides, based on the observation data reported, there are several activities that students conducted in order to plan the solution, such as: (a) acquiring the concept and writing the equations related to the problems; (b) coming up with the fundamental knowledge that they have learned; and (c) searching for information. The same activities have also been reported by [66]. Furthermore, during the interview session, the facilitators also reported that on week two, the students started planning the for solution by searching for information from various sources, engaging in discussions with friends and lab technician, and applying the fundamental knowledge that they already knew (e.g., electrical formulas). Furthermore, the students also determined the important variables they have to measure in order to simplify them to collect the results or determine the necessary output. This statement can clearly be discovered from the following interview excerptions:

"Supposedly, on week two, student should already understand the problem given and they have to ***start to prepare the procedure,*** *types of* ***equipment*** *that they want to use and its* ***configuration.*** *At the end of the meeting, I will reflect back what they have done on week two."*

(Participant F1)

"On week two, supposedly students already understand and know how to tackle the problem. They should ***already have the outline****. I will asked them how they want to solve*

the problem, what ***theory that they used,*** *what kind of* ***software*** *that they want to used and then, they will* ***setup the experiment*** *based on the theory that they choose. I will facilitate them.''*

(Participant F2)

''My lab is more on designing the hardware on week two. Student will find out ***what they are going to measure*** *and what the* ***suitable tools*** *to use. Then, students will start searching the datasheet and apply it to solve the problem.''*

(Participant F5)

''On week two, students have to present the information that they have found from previous week. Then, they ***started to write the code*** *in order to get the output that they have to obtain.''*

(Participant F6)

Based on the facilitators' views, it has been shown that, on week two, students better understood the problem, and already had an outline on how to solve it. This process can be observed clearly from F1 and F2's comments. Moreover, several activities that are important to plan the solution were discovered from the interviews. These activities were: (a) identifying the use of hardware or software tools; (b) applying the electrical fundamental knowledge; and (c) developing the procedures or code. These activities were clearly mentioned by F1, F2, F5 and F6.

Besides, it can be observed that the PB Lab course has given the students a chance to individually think about the steps or procedures that they had to follow in order to solve the given project. This is different from the previous traditional laboratory, which already prepared the procedures that the students must follow.

Normally, the process of conducting experiments is conducted in week three. The variation of when this process occurs depends on how the facilitators facilitate the students, and how fast the students can understand and solve the problems related to the given project in their groups.

6.3 Problem-based laboratory (PB Lab) week three (W3)

There were two main processes discovered that occurred in the PB Lab course on week three, which are: the plan implementation and the solution checking process. Both processes have been detected based on the observation and interview sessions. If the students have properly planned the solution, it will be easier for them to conduct the strategy selected during this phase. According to [65], during this carry through phase, there is a list of nine things to monitor, and one of them is to construct the experiment to discover whether the solution selected will work or not. The following excerpt was taken from the observed activities that involved implementing the solution phase in the PB Lab course:

The students started the laboratory session by directly ***conducting the experiments****.*

(Observation W3 Group B)

The students ***started searching*** *and identify* ***devices*** *that they wanted to use.*

(Observation W3 Group A)

The students got the component that they wanted to use and they started to ***discuss*** *the* ***function of each component****.*

(Observation W3 Group C)

The students have ***completed*** *their* ***simulation.*** *They were trying to* ***transfer*** *the circuit connection (like they design in the simulation) into the* ***real trainer.***

(Observation W2 Group D)

This phase clearly shows that the students implemented what they have planned to solve the problem. They started to identify and define the tools that they want to use, write the coding, and try to run the software in order to get the results. Normally, these steps are the most straightforward steps in the problem solving process if the students have proper strategies to reach a solution [67]. Mental processing occurs when the students try to apply the concepts they have learnt in class to solve the given problems in the laboratory. Besides, when it comes to the process of collecting the data or the output of the experiments in different forms (such as graphs, signal and numbers), the students go through another mental process, where they attempt to interpret the results on week three, followed by presenting a strong solution in front of the panels on week four. In short, these activities show that there are several individual thinking processes involved during this PB Lab session.

Besides that, checking the solution is another process that took place in the PB Lab course. This is among the hardest steps in the problem solving process, and involves several thinking processes to interpret whether the results that have been obtained make sense or not toward the problem. In the PB Lab, the checking phase, or troubleshooting phase, involved several of thinking process, discussions among group members, and facilitation from the facilitators to obtain the best solution. The following are examples of several excerpts taken from the observation data:

The facilitator came to the students and ***checked their circuit*** *that they have connected on the trainer. Then, the students* ***tried*** *to* ***troubleshoot*** *the circuit until the circuit is completed and they* ***got the results****.*

(Observation W3 Group C)

The circuit connection made by students was wrong, so they had to ***re-do it****.*

(Observation W3 Group B)

The students ***checked*** *the circuit connection and tried to* ***get the results*** *using* ***oscilloscope.***

(Observation W2 Group D)

The students ***compare the results*** *that they obtained* ***from***

> ***the simulation*** *with the results* ***from the trainer.***
> (Observation W3 Group D)
>
> *The facilitator* ***checks the student's experiment results*** *and* ***asked their understanding*** *about the obtained results.*
> (Observation W3 Group A)
>
> *The facilitator instructed the students to* ***draw the graph and explain*** *to him.*
> (Observation W3 Group C)

Based on the observations, it can be seen that, during this phase, students applied all of the information that they obtained from the facilitators, graphs, simulation results and from their previous knowledge, in order to interpret the output that they acquired. If the output or results they obtained are not correct and cannot solve the problem, the students will troubleshoot the design or the coding development again. Thus, this process leads to high thinking skills by the students in order to interpret the results and compare them with the theory. Furthermore, based on the interview sessions, the same processes have also been discovered. Several examples of the interview excerption are as follows:

> *Then, on week three, student will* ***started the experiment*** *and the technician will facilitate them in order to make sure* ***the connection that they build up is correct****. Normally, I will look at and* ***check their experiment results****. At the end of week three meeting, they must reflect back the output that they got, and what can be conclude based on the results. They have to* ***match the results obtained and the theory behind it.***
> (Participant F1)
>
> *The students already knew what to do on PB Lab week two and they just proceed the work on week three meeting. They will* ***connect the devices*** *on week three and normally the connection will have a problem. I will ask them one by one and* ***they have to troubleshoot the circuit until got the correct results.***
> (Participant F2)
>
> *The students will* ***proceed with the experiment after the procedures that they design have been approved.*** *Then, they will start* ***searching the devices*** *to use.*
> (Participant F3)

Based on the facilitators' explanations, it had been discovered that, after the planning phase, students directly implemented the procedures or designs that they discussed. This can be seen in F1, F2 and F3's statements, which reported that students started "connect the devices", and "set up the experiment", on week three. Besides, there was also a "looking back" phase where the facilitator checked the students' connection and outputs in order to justify the correctness of their results. During this phase, students compared the hardware or the software results that they obtained with the fundamental knowledge that they learned in class.

6.4 Problem-based laboratory (PB Lab) week four (W4)

The final problem solving process which has been discovered after the solution checking in the PB Lab course was the evaluation of the solution. Commonly, the evaluation of the solution occurred on week four, during which the students presented their solutions in front of the panels. During this phase, the panels evaluated their solutions based on the design, results and methods that they used. At the same time, the students also evaluated the solutions that they used in order to identify their mistakes. Several examples of the activities during week four based on observation are as follows:

> *The students began the presentation by* ***introducing the problem*** *that they obtained, followed by the* ***method that they used****.*
> (Observation W4 Group D)
>
> *The facilitator* ***asked the students questions*** *regarding the* ***methods*** *that they used. The students seemed difficult to answer the question.*
> (Observation W4 Group B)
>
> *The facilitator provided* ***comments to students*** *to indicate that* ***their results are not reaching satisfactory level.***
> (Observation W4 Group C)
>
> *While students were presenting their project, the facilitator* ***asked them some theories*** *related to the project but the students could not answer it.*
> (Observation W4 Group C)

The above excerptions show the process that occurred in the PB Lab course on week four. This process is likely the same process identified in the interviews data. The facilitators' feedback on the process that occurred in the PB Lab on week four is as follows:

> *After that, they just* ***present their results****.*
> (Participant F1)
>
> *On week four, the student* ***will present*** *and they will* ***take note comments*** *from the panels. At the end of the session, they will be asked to prepare a report.*
> (Participant F2)
>
> *The student will* ***present the solution*** *and they* ***will be asked*** *during the presentation on week four.*
> (Participant F4)

By looking at the statements from F2 and F4, it can be observed that, during week four of the PB Lab course, students already finished their experiments or designs, and they went to the PB Lab session to present their outcomes. The questions and answers session was held during this presentation phase. Although this final PB Lab activity on week four only required the students to present the solution and results, it involved several problem solving processes, since the students were asked questions during the presentation. In addition, the students must clearly understand what they have done in order to solve the problem and obtain the results. In order to enhance students' problem solving skills, the educators should evaluate not only the correct-

Table 3. The summarization of the observation and interviews results

Weeks	Themes (Identified Elements of Problem solving Process)	(Codes) Observation data	(Codes) Interview data
Week 1	Problem Identification	• find information from the internet • brought books and read articles from e-journals • briefing about the concept of Unipolar and Bipolar electrical circuits • discussion among group members	• try to understand the problem identify the problem statement brainstorming search for related information from the internet • identify the related journal paper
Week 2	Project Planning	• seemed to understand some references • brought laptops • read journals • showed the simulation • Asked the electrical fundamental knowledge • apply the formula • find information from the internet • draw the circuit connection	• start to prepare the procedure and equipment they want to use and its configuration • obtained the outline • theory that they used • setup the experiment • find out what to measure and the suitable tools to use
Week 3	Implementing Engineering Design	• conduct the experiments • obtained the component that they wanted to use • discussed the function of each component • transferred the circuit connection (simulation) into the real trainer • search the devices to use • match the results obtained and the theory behind them • draw the graph and • obtain the results using oscilloscope	• connect the devices • connection will have a problem • troubleshoot the circuit until the correct results are obtained
	Project Analysis	• checked their circuit • tried to troubleshoot the circuit until the circuit is completed and got the results	
Week 4	Evaluate the Solution	• asked theories • the facilitator provided comments to students	• present their results • take notes based on comments from the panels

ness of the product of the solution, but also the process of finding the solution [67].

In conclusion, the above discussion reflects the problem solving processes that occurred in the PB Lab course. The summarization of the observation and interview results are presented in Table 3.

Table 3 clearly shows that there are five problem solving processes which have been discovered based on observation and interview data from week one until week four. Students themselves face many problems solving issues while working on the project given in the PB Lab course. They had to understand and define the key issues of the problem, and attempt to come out with strategies to solve it, and in turn, reach a possible solution. This process is similar to the problem solving deliberation process proposed by [39], where people have to solve the problem by ''recognising the existence of the problem itself, identifying the nature of the problem, developing hypotheses to solve the problem, testing the hypotheses followed, and selecting the most appropriate alternatives among the hypotheses. Besides, [68] also explained that problem solving is a process in order to obtain the best solution to an unknown (or a decision) that is subject to some constraints. Normally, a well-structured or an ill-structured problem is given to students to be solved. Students will try to understand the given problems and discuss them with their group members; they will then come out with several proposed solutions. This form of learning activity is actually a process of thinking that students apply in order to solve problems. Sometimes, without being told, this process of solving problems is naturally adopted by students, although the final state of problems remains unclear. This statement is similar to the definition of problem solving proposed by [69] who defined problem solving in the engineering context as ''the process used to determine the best answers to an unknown, or a decision subject to some constrains''. The term ''process'' is defined as the steps-by-steps that the students must go through in order to solve the problems, whereas the terms ''best answers'' and ''subject to some constraint'' emphasize that, in solving real-world problems, the students will face challenges, namely, lack of information and not enough resources. Based on the limited amount of information, students have to think and apply the best solution in order to get the best possible answer.

7. Quality of the research finding

In order to validate the determined problem solving processes investigated by the researcher, there are two methods that have been used by the researcher: triangulation and measurement of percent agreement. The finding given by the triangulation of observation and interview (Table 3) reported five problem solving process in the PB Lab course. These processes were: (a) problem identification, (b) plan the solution, (c) implement engineering design, (d) project analysis, and (e) evaluate the solutions. These triangulation results provided strong evidence that were several problem solving processes that occurred among students in this course. Furthermore, three facilitators from the PB Lab who have experience in conducting the PB Lab course and several experts in the electrical engineering domain have reviewed and validated these data. The experts have completed the agreement forms provided by the researchers, and the results of these forms have been analysed using the percent agreement measurement. This measurement method has been used because it helps the researcher to identify the degree of agreement, and gives a simple estimation of the reliability value between the raters [70] . Hence, the value of percent agreement was calculated, and the results are shown in Table 4.

Based on the finding above, there was a reliable and high agreement between the raters. The percent agreement between rater A and B was 76.8%, between rater A and C was 83.9%, and between rater B and rater C was 90.9%. Based on [71], the accepted value for the percent agreement is 70%. Due to that, the above percent agreement results indicate that most raters agreed on the determined problem solving process that occurred in the PB Lab course from week one until week four. It is clearly shown that there are five main problem solving process that occurred based on the triangulation of interviews and observation data. The triangulation results supported by the percent agreement measurement clearly show the processes of problem solving that occurred in the PB Lab.

Table 4. The Percent Agreement Results

Raters	Percent Agreement (%)
Rater A vs Rater B	76.8
Rater A vs Rater C	83.8
Rater B vs Rater C	90.9

8. Conclusion

In light of recently required engineering accreditation board program outcomes and demands from the industries, many active teaching and learning approach has been developed and implemented by engineering educators. However, less studies or initiatives have been done in reviewing the implemented learning approaches, whether it has truly been implemented with the elements of problem solving skills in it or otherwise. Due to that, this study aimed to review and determine the elements of problem solving strategies that may have occurred in a Project-based Laboratory (PB Lab) course at Faculty of Electrical Engineering, Universiti Teknologi Malaysia. Four groups, each of which consists of five students and one PB Lab facilitator, were observed and seven PB Lab facilitators were interviewed in this study. By using the thematic analysis technique, the results of the analysis have indicated that there are five main processes associated with the problem solving elements that took place during the PB Lab course activities which are (a) problem identification (b) project planning (c) engineering design implementation (d) project analysis and (e) solution evaluation. These elements are similar to the five-step problem solving process proposed by Dewey's problem solving model. In addition, these elements have also been determined as one of the main factors which have led to the enhancement of students' problem solving skills in this laboratory context. Besides, the interview and observation results have also clearly proven that the students have indeed gone through the process of improving their skills in solving the problem at hand. Further investigation and analysis need to be done in future to identify other factors that may affect the students.

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