

## A quasi-experimental study researching how a problem-solving teaching strategy impacts on learning outcomes for engineering students

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**ABSTRACT:** One of the major goals of engineering education is to cultivate students' problem-solving abilities. However, current engineering education programmes have been criticised for not meeting such demand in this era of the knowledge economy. Traditionally, engineering students were taught using a lecture teaching method. Students majoring in various fields were asked to take different courses in order to graduate. They regarded themselves as competent in these fields, whether or not they learned how to face problems. Therefore, the purpose of the article is to determine the effectiveness of a problem-solving teaching strategy on the learning outcomes of the Power Wiring Course (including problem-solving attitude and ability) for engineering students. Hopefully, the results of this study can be applied to engineering teaching to cultivate students' problem-solving abilities. The quasi-experimental unequal control group design was used in this study. The study's major findings include significant increases in students' problem-solving attitudes and abilities after implementing a problem-solving teaching strategy. Some recommendations in using problem-solving teaching strategies more effectively are also proposed for instructors in engineering education.

### INTRODUCTION

The problem-solving skill is an important intellectual activity for human beings; it is also a very important springhead of humankind's knowledge [1]. Psychologists treat it as a complicated but highly structural progress of mental activities in human beings. The development of problem-solving skills is a main target in developed countries; it is also the core ability in engineering education [2]. In order to expand students' abilities in a specialised field, instructors should guide students to think, make decisions and apply knowledge to new settings. This will lead students to do problem-solving work smoothly, whether in or out of school.

As a practical course, the teaching programme of the Power Wiring Course is a prescribed subject for students in the electric machinery field; it is also the most important module in the training programme. The teaching objective of this course is to let students become familiar with and understand the common uses of industrial wiring components and, furthermore, understand the basic theory of system control and the application of this basic theory to every kind of industrial control components [3]. Xu and Lai also pointed out that the Power Wiring Course was taken by students to develop their analysis and design abilities in industrial control circuits [4]. This would help students establish the concept and technique of the entire control system. As such, improving students' problem-solving abilities in the Power Wiring Course is very important.

Gagné considered *problem-solving* as a high-level deliberation ability that should have the following inherent conditions:

- Arouse pre-preparing skills;
- Interact with the contents of new studies in many different ways;
- Apply new skills into different environments [5][6].

Gagné was of the view that, once the *problem-solving* skills are developed for students, students should also be set up for new settings. In addition to this, Cox deemed that during the problem-solving activities, knowledge in a specialised field is not enough for students, they also need the findings of the tactics of problem-solving, the foundation knowledge about problem-solving, and information in other related non-specialised fields [3][7].

Reaching a solution requires algorithms or heuristics [8]. An algorithm is a procedure that guarantees a solution, such as an algebraic formula. The drawback with the use of algorithms is that they are not available for every problem. Heuristics, on the other hand, do not have the limitations that algorithms have, although they may not provide the answer directly. Common heuristics methods incorporate: simplifying the problem; means-end analysis; working backwards; pattern recognition and trial and error [9].

Taking on board Cox's perspective, one can state that, in addition to domain-specific knowledge, problem-solving activity requires strategy to create problems, a knowledge base of solvable problems plus other additional information, such as domain free-knowledge. Following Cox's ideas, supplemental teaching materials, including the above items, were developed for this experimental design study.

A problem-solving teaching strategy is a teaching method that focuses not only on solving problems, but on providing some supplemental instructional materials to cultivate students' independent thinking abilities, fact-finding abilities and scientific attitudes.

In this study, a supplementary instructional unit, including ten units of Power Wiring: Basic Control Electrical Circuit was developed to construct students' heuristics pertinent to

electrical circuit problem solving. The experimental group studied the supplementary instructional unit. This research focused on an analysis of the progress of electrical circuit troubleshooting in the Power Wiring Course, which requires that students develop skills in repair and replacement, diagnosis and testing, as well as application.

## PURPOSES

Based on the aforesaid rationale and research background, the main purpose of this study was to understand the effect of a problem-solving teaching strategy on the development of problem-solving skills for engineering students in the Power Wiring Course. This research has the following objectives:

- To compare differences in problem-solving attitude between the traditional teaching strategy and a problem-solving teaching strategy on engineering students.
- To compare the differences in problem-solving abilities between the traditional teaching strategy and a problem-solving teaching strategy on engineering students.
- According to the conclusions of the research, provide recommendations to improve problem-solving teaching strategies in engineering education and to develop students' problem-solving abilities.

## METHOD

The quasi-experimental research method was used in the study to achieve the research purposes. The subjects were junior students of the Automatic Control Department at Taipei University of Technology, Taipei, Taiwan, and the experimental period was six weeks. Due to the organisational system of classes at the University, random sampling could not be utilised for the study. Under this condition, the quasi-experimental design was used to obtain adequate control of sources of invalidity, and a non-equivalent control group design that did not involve the random assignment of each subject to groups was adopted [8]. The research design matrix is shown in Table 1.

Table 1: Mode of the experiment design.

	Experimental	Controlled	Total
Male	37	37	74
Female	5	2	7
Total	42	39	81

This research took the whole class as the random unit. Two existing classes were randomly assigned as either the experimental group or the control group. There were 42 students in the experimental group and 39 students in the control group. The numbers of samples are shown in Table 2. The framework of this study is shown in Figure 1.

Table 2: The distribution of the formal sample.

Group	Pre-test	Experiment control	Post-test
Control	Y3	.	Y4
Experimental	Y1	X	Y2

These two groups were pre-tested, administered a treatment, and then post-tested. An advantage of this design is that since

classes are used *as is*, the possible effects from reactive arrangements are minimised. Indeed, subjects may not even be aware that they are involved in a study.

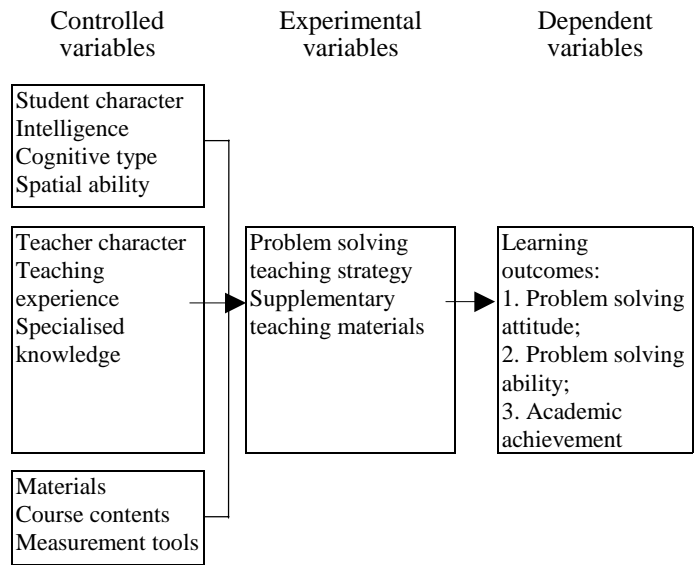


Figure 1: Framework of the research.

The progress of this study contained a literature review, the design of the teaching programme (including the development of teaching materials), the development of the scale of the problem-solving attitude, the development of the scale of the problem-solving ability, sample selection, pre-test, experimental teaching, post-test, the compilation of data, and the analysis of data. The experimental group and the control group used the same textbook and learned the same course contents. All students were from the same Department, and the instructor was the same. Possible attributes that could affect the study's results were controlled to be as identical as possible.

The administration of the experiment was based on whether the supplementary teaching materials were provided or not. The experimental group was provided with supplementary teaching materials, and the knowledge and skills needed to solve problems were taught. But the control group was taught using the traditional teaching strategy without providing any further supplementary teaching materials except textbooks.

Discussion on the dependent variables provided the differences between the experimental group and the control group in terms of the problem-solving attitude and ability.

## INSTRUMENT

There are two instruments for the evaluation of the study. These include *the scale of problem-solving attitude* and *the scale of problem-solving ability*. The items for the scale of the problem-solving attitude were compiled through three assumed factors, namely: the hesitated avoided style, the confidence of the problem solving and the control of the personality [10]. The validity of the scale was then established through factor analysis. Factor extraction was done through oblique rotation. Those items whose commonalities had Eigen values greater than one were retained. The results of factor analysis indicated that these three dimensions could explain 41.2% of the variance. The reliability of the scale of the problem-solving attitude was presented as the Cronbach  $\alpha$  and the re-testing coefficient. The  $\alpha$  coefficient was between 0.723 and 0.827 on

each scale, and 0.877 on the total scale. The re-testing reliability was taken within three weeks. Except that the first dimension is 0.684, the re-testing coefficient of the rest dimensions is between 0.792 and 0.793. The re-testing reliability of the total scale achieved a value of 0.883, which has a 0.01 significant level. This indicated that the reliability coefficient of this scale is very reliable.

The definition of the scale of the problem solving ability is based on the requisite ability to eliminate the malfunction, which was provided by Perez. This can be divided into three categories: *repair and replacement*, *diagnosis and testing*, and *strategy application* [11]. According to these abilities and teaching contents, the test items for these three categories were made by using a two-way table of specification.

After the test items were made, five experts were asked to evaluate these items in order to ensure their validity. Since the repair and replacement ability was defined as cognitive and procedure knowledge, the test items were made in the form of multiple choice. The draft of this scale was then pre-tested. The test items that had a value with a difficulty index between 0.3 and 0.9 and a discrimination index above 0.2 were retained. The reliability of KR-20 for this scale was 0.896. The instructor and the researcher, according to their testing actions and strategy applications, evaluated students' responses on the test items for the measurement of diagnosis and testing and strategy application. The scorer reliabilities for these two scales were 0.984 and 0.953 respectively.

#### Supplementary Teaching Materials

Olstad and Haury suggested that researchers should identify domain-specific and domain-free methods of information processing, as well as define strategies in order to bring these methods together in a problem-solving situation [12].

The researchers identified the recognition of electrical circuit operational principle as a domain-specific information processing technique and the strategy of logical reasoning as a domain-free information process. The strategy to bring these two together was accomplished via a supplementary instructional unit.

The supplementary teaching material for problem solving in this research includes three parts: motivation promotion, training in general problem solving, and training in professional problem solving. There are two units for motivation promotion, three units for training in general problem solving, and five units for training in professional problem solving. These units were embedded into the formal teaching units.

#### Experimental Teaching

The design of the teaching programme was based on the framework and the construction of this research. The teaching experiment was held for eight hours per week over six weeks, totalling 48 hours. During the teaching treatment, the problems were taken as the central part for instruction in the experimental group, and all of the learning events were based on real life situations in the world around them, such as the explanation of the controlled circuit of the motor in the phenomenon of the rolling electrical door. The idea behind this was not only to present the problems to students, but also to provide useful resources to students so that they could solve problems independently.

Using Dick and Carey's instructional design model, a supplementary instructional unit for the experimental group was developed by the researchers [13]. The instructional materials explained in a step-by-step manner each circuit diagram operation principle in order to identify clearly one component's relationship to other components in the circuit. A supplementary instructional unit that described how to transfer one complex electrical circuit into simple linear diagrams for troubleshooting was given to the experimental group. To maintain students' interest and encourage interaction with the supplementary instruction, the instructional handout described selected power wiring circuit problems that would be assigned to students during their course of study. The control group did not receive any additional instruction.

The final outcome was a linear circuit diagram for troubleshooting. Each linear diagram clearly represented series and parallel relationships among the circuit components; students then had to find out the point of trouble in each electrical circuit. Examples of the unit described selected circuit problems that would be assigned to students during their course of study.

#### FINDINGS

Comparing the pre-test scores of the experimental and control groups using a t-test analysis revealed that there were no significant differences in terms of problem-solving attitude and problem-solving abilities. The results should be expected, since the college entrance examinations are used to screen students in Taiwan. The attributes of students in the same Department should be very homogeneous.

However, there was a significant difference in the problem-solving confidence on the attitude scale. There were significant differences between the experimental group and the control group with regard to the factors of repair and replacement, diagnosis and testing, as well as the strategy application of the scale of the problem-solving ability. The results are shown in Table 3. This indicates that the problem-solving teaching strategy did help students increase their problem-solving attitude and abilities. Wang achieved similar results in her research; she pointed out that a problem-solving teaching strategy could help students increase their problem-solving attitude and ability, and their adaptation ability [14].

#### RECOMMENDATIONS

Nowadays, one of the key objectives of engineering education is to cultivate students with problem-solving abilities. In traditional instruction, teaching means explanation, demonstration and evaluation. However, this will not cultivate problem-solving abilities. In this research, a problem-solving teaching strategy was utilised in order to examine its function in cultivating students' problem-solving attitude and ability in engineering education. The results are promising. Therefore, engineering educators should be encouraged to use a problem-solving teaching strategy in their instruction as much as possible so as to promote the problem-solving abilities of their students.

According to the results of this study, the researchers would like to make some recommendations from both of the concepts of the teaching in school and further research for engineering educators to refer to.

Firstly, there should be an infusion of problem-solving skills into professional problems. Problem-solving skills are not independent from a specific discipline. It may be important to give students general ideas of problem-solving skills. However, problem-solving skills should be *embedded* into professional problems. The teaching of problem-solving skills need not necessarily be independent. The introduction of problem-solving skills through the real problems that connect with professions is a better way for learning.

Secondly, there should be a selection of problem-solving skills for different issues and situations. Each problem-solving skill has its own property. Different problem-solving skills will fit different issues or situations. This can be identified through the nature of knowledge and skills of the disciplines. Instructors should identify those problem-solving skills for different contents.

Thirdly, there should be a selection of problems from the real world. Problems that are used in the classroom for teaching should be chosen from the real world and have theoretical connections with the contents. Both theory and practice are taught in engineering education. Therefore, problems are used to examine such theory and practice. This means that problems for students to solve are not ends but *means*. Problems chosen for teaching are used to increase students' attitudes and abilities in problem solving.

Fourthly, there should be a continuation of adoption of problem-solving teaching strategies. The development of students' problem-solving attitudes and abilities cannot be achieved over a short period of time. The adoption of a problem-solving teaching strategy should be continued over the long term in order to reach the expected results.

Fifthly, the use of electrical games should be encouraged. Many electrical games or computer simulations have been recently designed to help learners understand the process of problem-solving by operating programs. These packages can also help learners develop problem-solving abilities, especially regarding strategy application and creative ability. Therefore, instructors can select those electrical games and simulations that fit the needs of learning for students to cultivate their problem-solving skills.

Sixthly, there should be a study on the variables affecting problem-solving skills. The discussion of the problem-solving ability in this research focused on overhauling malfunctions and eliminating faults in a power wiring training course. However, as Tsai pointed out, factors that affect learning achievement on problem-solving skills need to be studied [1]. The teaching of problem-solving skills could use or control identified variables to increase its effectiveness. Therefore, more research and investigations need to undertaken on such factors.

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Table 3: Analysis of the learning outcomes of different teaching strategies.

Learning outcomes	Test of the difference	Problem solving attitude			Problem Solving Ability		
		Confidence	Style	Control	Repair	Diagnosis	Strategy
	Dimension	Experimental Group (24.286)> Control Group (22.744)*	--	--	Experimental Group (68.38)> Control Group (60.51)*	Experimental Group (67.26)> Control Group (56.15)*	Experimental Group (41.91)> Control Group (29.62)*

\*p<0.05