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ENGINEERING STUDENTS' RETENTION AND TRANSFER OF LEARNING FROM TRIGONOMETRY TO ELECTRIC CIRCUITS

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ABSTRACT

This research article explored engineering students' retention and transfer of learning from Trigonometry to Electric Circuit courses. The study used a descriptive quantitative and qualitative research designs. It utilized both written exams and semi-structured interviews to investigate the retention and transfer of learning. Results indicated that students retained their knowledge of the Trigonometry concept before entering an Electric Circuits course but encountered difficulties in transferring retained knowledge in a new context due to difficulty in deciding when to activate appropriate Trigonometry concepts. Likewise, they just follow the formulas given in the electric circuits lecture and did not take into consideration the underlying trigonometric principles used in deriving the formula. Thus, students often resorted to pattern matching while approaching their problems. This study has implications for the instruction of both engineering and mathematics education.

INTRODUCTION

There is a debate about whether future engineers are mindful of the connections between the mathematics they study early in their degree and the later engineering subjects. Among most engineering faculty and instructors, they observed that students' performance on mathematical problem solving was low [1] or below the average. One interpretation is that students lack the requisite mathematical knowledge to solve mathematical problems in engineering. An alternative interpretation is that students do not know how to apply the mathematical knowledge they have learned in mathematics classes to the context of engineering courses which is also known as the transfer of learning [2]. Fleshing out exactly why students perform poorly on mathematical

problem-solving tasks in engineering courses could have important implications for engineering curriculum and instruction.

Inadequate and below-average mathematical higher-order thinking skills [3] present a widespread problem throughout engineering undergraduate programs. "However, specific, well-documented examples of student difficulties are often lacking, and the exact nature of the difficulty is frequently uncertain [4]". Besides, mathematics and engineering faculty did not focus on discussing mathematics skills related issues and frequently presume that certain engineering concepts are tackled in the mathematics courses [5]. The level of mathematics skills of engineering students at the Nueva Ecija University of Science and Technology has been identified as a problem by a number of the faculty that teach core subjects in the Electrical Engineering department.

This issue manifests itself in a number of ways and, in particular, has a negative effect on students' ability to grasp engineering subject material. Specific problems are observed during lectures, where questions often arise regarding basic mathematics manipulations. Therefore, it is important to take a close look at how students transfer the knowledge [6], [7], they learned in mathematics when they are solving a problem in engineering courses, and find strategies to facilitate the transfer process given the constraints of most universities that require students to take mathematics courses and engineering courses asynchronously from different instructors, residing in different departments, and who may not necessarily communicate the goals and needs of their students with each other.

One major subject in engineering that has a connection to Trigonometry is Electric Circuits. It is a major subject being taken by electrical engineering students in the Nueva Ecija University of Science and Technology (NEUST). The relationship between Trigonometry and Electric circuits is obvious both from the historic view and real-world views [8]. "Electricians and Engineers used math concepts to ensure that the wirings and electrical components they utilized will work according to the design. Without this knowledge, each circuit may not work and can even cause serious damage to a circuit. They also use Trigonometric calculations in day-to-day tasks, such as bending conduits [9]."

However, some engineering professors in NEUST claim that their students do not have enough knowledge in Trigonometry that will help them understand and be proficient in Electric Circuits. If this is the case? Research on the transfer of learning from Trigonometry to Electric Circuits is necessary and relevant. Thus, the researchers specifically, it aimed to: determine the extent to which the students retain what they have learned from the Trigonometry course when they begin their electric circuits course; determine the extent to which the students transfer what they have learned in trigonometry to problems in electric circuits, and determine the difficulties students have in transferring what they have learned in Trigonometry to Electric Circuits.

METHODOLOGY

Central to traditional approaches to transfer is a dominant methodology that asks whether people can apply something they have learned to a new problem or situation. Transfer of learning occurs whenever previously learned knowledge and skills affect the way in which new knowledge and skills are learned and performed [10]. "There are three ways in which transfer can occur: from prior knowledge and skills to new learning, from new knowledge and skills to new learning situations, and from new knowledge and skills to applications in work and daily life (learning for practice)

[11]". An example of the first category of transfer is a Filipino student who learns to read an English text and uses knowledge and skills from his or her native language (Filipino). This perspective in analyzing transfer was the basis of this research. The study used a descriptive quantitative and qualitative research designs. It used both written exams and semi-structured interviews to investigate the retention and transfer of learning from Trigonometry to Electric Circuits. To determine students' retention of concepts in Trigonometry, a test containing pure trigonometric concepts was administered to 50 electrical engineering students who are enrolled in Electric Circuits II (EE 325) at the NEUST. Students' retention of concepts in Trigonometry was analyzed with respect to their performance on the test.

The test on the Trigonometry concept was part of Section A of the transfer test which was also administered to the same students. Section B of the transfer test was comprised of electric circuits based questions using the same mathematical concept tested in Section A. Using the results of the test, a measure of transfer based on the instrument designed by [12] to determine the transfer index between the two sections of the test was used. Each question in section A was mapped to a question in section B that required the use of the same trigonometry concept, generating pairs of mapped questions. If a student gave the right answer in both sections, they were given 2 for that set of questions. If they did not get it right in both sections, they were given 0. If they answered section A correctly but did not get the corresponding question in section B correctly, they have given 0, as this does not indicate that transfer has occurred. Lastly, if they answered incorrectly on Section A but correctly on Section B, they were given 1 for that set of questions. This reflects the view that transfer has occurred, but to a lesser degree than when answering correctly on both sections. There may be a subconscious process at work when answering section A that prepares students for Section B.

There are 20 pairs of mapped questions in the test. The overall Transfer Index given to a student is the normalized sum of the individual transfer scores on the 20 pairs of mapped questions.

The transfer index is given by the formula:

$$Transfer\ index = \frac{\sum_{n=1}^{20} Transfer\ Score}{40} x100$$

The students who took the written examination were interviewed within two weeks of completing the test. The interview was semi-structured with the goal of eliciting information about the students' difficulties in transferring their knowledge in Trigonometry in solving problems involving Electric Circuits concepts. Students' retention of concepts in Trigonometry was described in terms of the percentage of correct answers obtained in the test.

Table 1. Interpretation for Retention of Concepts in Trigonometry

Percentage of Correct Answers	Verbal Interpretation
81-100%	Very Satisfactory
61-80%	Satisfactory
41-60%	Fair
21-40%	Not Satisfactory
0-20%	Poor

The extent to which the students were able to transfer their knowledge in Trigonometry in solving problems in Electric Circuits was described using the scale in Table 2.

Table 2. Interpretation for Extent of Transfer of Knowledge

Transfer Index Percentage	Verbal Interpretation
81-100%	Very Satisfactory
61-80%	Satisfactory
41-60%	Fair
21-40%	Not satisfactory
0-20%	Poor

RESULTS AND DISCUSSION

The findings of the study revealed the following:

1. In terms of students' retention of concepts in Trigonometry, out of 50 students, 27 students (54%) registered a very satisfactory performance, 9 students (18%) with satisfactory performance, 7 (14%) students with a fair performance, 5 (10%) students with not satisfactory performance, and 2 students (4%) with poor performance.
2. In terms of the extent to which the students were able to transfer their knowledge in Trigonometry in solving problems in Electric Circuits, 16 students (32%) obtained a very satisfactory performance, 12 students (24%) with satisfactory performance, 8 students (16%) with a fair performance, 8 students (16%) with a not satisfactory performance and 6 students (12%) with poor performance.
3. Interview results indicate that students did retain their knowledge in Trigonometry but had difficulties in transferring their Trigonometry knowledge when solving a problem in Electric Circuits. Students had difficulty deciding when to activate appropriate Trigonometry concepts. More than half of the interviewees admitted that they just follow the formulas given in the Electric Circuits lecture and did not take into consideration the underlying Trigonometric principles used in deriving the formula. Thus, students often resorted to pattern matching while approaching their problems. Likewise, the interview with the students revealed that they were inconsistent in the use of their understanding of Trigonometric concepts when encountering these ideas in new contexts. Most of the students were not aware of the similarities between the two sections of the test and find the Electric Circuits part of the exam more difficult than the Trigonometry test.

CONCLUSIONS AND RECOMMENDATIONS

Students appeared to retain their knowledge of Trigonometric concepts since most of them were able to correctly solve the problems in the test. Although the majority of the students possess the requisite Trigonometry skills, a great number of them failed to use or interpret in the very vital context of solving problems [13] in Electric Circuits. Likewise, students had difficulty associating variables in Electric Circuits problems with their knowledge in Trigonometric concepts. They have difficulties in transferring their Trigonometry knowledge when solving a problem in Electric Circuits. Based on the results, mathematics faculty could devote time deliberating the applications as well as the conceptual foundations rather than concentrate solely on approaches and procedures to solve problems [8]. They should introduce related word problems involving the applications of Trigonometry to the real world of work. Lastly, engineering faculty members should develop activity-based books [14] that will engage

students and made the students realized that mathematical concepts can be applied in the engineering profession.

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