CHAPTER I

INTRODUCTION

The main goals of introductory physics courses are to guide students to i) understand physics concepts and ii) learn to apply them to relevant problems. Because individuals have different learning styles, some students will find that the course presentation does not suit them and will struggle with the physics material. Ideally, lessons would be tailored to each of them. But this is often a practical impossibility because of class sizes and limited resources. The typical number of first-year engineering students at Suranaree University of Technology (SUT) is around 2000 students. When they take Physics I, either in the first or the second group, the students are distributed into several sections of 200 to 300 students. It is challenging to develop effective teaching strategies that might achieve the course goals.

Many studies have shown that pre-instruction mathematical skill and student performance in introductory physics classes have positive correlation (Hudson et al., 1977; Hudson et al., 1981; Hudson et al., 1982; Meltzer 2002). It is not surprising that aptitudes for mathematics and physics are correlated; however, a detailed picture of how a knowledge of a particular concept in mathematics impacts the student's ability to learn to solve problems in specific areas of introductory physics would be helpful in crafting physics instruction. That is, if we understood which mathematical skills are vital for acquiring a certain physics problem-solving skill, then we could design the physics course with such connections in mind. This may help provide some of the benefits of an individualized education to SUT physics in spite of limited resources and time constraints. It is reasonable to suppose that insight gained into the case of SUT students will be of interest to the general physics education community.

For this thesis work, we are interested in investigating correlations between first year SUT engineering students' pre-instruction mathematics knowledge and their physics 1 course performance. These are the research questions of our study:

1) Which pre-instruction mathematics topics do SUT students struggle with the most?

2) For which mathematics topics if any, is the prior knowledge of students a reliable predictor of physics course performance?

3) Is there an observable gender gap in the following: pre-instruction mathematics knowledge, physics exam performance, or the correlation between the two?

In 2020, just prior to the shutdown of in-person classes imposed by Covid restrictions, SUT physics instructors administered mathematics tests to two groups of incoming first-year engineering students before they began their university physics courses. The first and the second group took the introductory physics course in the first and second trimester respectively. With these test results, as well as the physics exam results, we did the corresponding statistical analyses to address the above questions.

1.1 Literature Review

It is not surprising that mathematics knowledge is necessary for those who want to learn physics, as physics is a quantitative study of nature. Certainly, those who struggle with mathematics are expected to have a hard time solving physics problems (Redish, 2006; Sidhu, 2006). Many studies suggest that the relationship between university students understanding of mathematics and physics is complex, since students need more than mathematical skills to effectively learn physics (Sweller, 1998; Ince, 2018; Franestian et al., 2020). Within the body of literature, there are two common approaches to study this connection. The first is to consider the correlation between pre-instruction mathematics knowledge and students' final grade in a physics course. The second is to consider the correlation between pre-instruction mathematics knowledge and students' learning gain in a physics course.

In a study at the University of Houston, the researchers investigated the relationship between pre-instruction trigonometry and algebra knowledge and physics performance (Hudson et al., 1976). They had their 194 students took a pre-instruction 30-minute mathematics test. The exam consisted of 18 questions, all related to algebra and trigonometry, and they found that Pearson product moment correlation between the test scores and the final physics grades is positive but weak, meaning that the final grade tends to be slightly higher with the mathematics test score. A few years later, a similar result was found for 913 students, who completed the same course (Hudson et al., 1981). The number of mathematical questions, in this latter work, was increased to 28. The researchers concluded that the pre-instruction mathematics knowledge alone did not guarantee success in physics. In addition, they found that score of the mathematics pre-test did not predict the students' drop-out rate. Later work by the same group investigated the combined effect of students' mathematical skill and operational reasoning on success in physics (Hudson et al., 1982). By having another group of students take an additional test of formal operational reasoning. A stepwise multiple regression analysis was used to determine the combined effect and it was found that the correlation of the combined effect on students' success in physics was significantly stronger than mathematics alone.

As mentioned above, another approach to study the connection is to look for correlation between students' scores on a mathematics test taken before a physics course and the students' learning gain in physics over the duration of the course. The learning gain is defined as the relative change in grades obtained in same test that administered as pre-test and post-test. The idea is that previous knowledge in mathematics may affect students' ability to improve their understanding of physics. In Meltzer's work (Meltzer, 2002), the students took a mathematics test and a test on the physics of electricity on the first day of class (this physics test is termed the pre-test). The scores were compared to their final examination grades in this electricity course. It was found that the pre-test physics score did not significantly correlate with the normalized learning gain, the ratio between the different between pre-test score and post-test score on the same test and the maximum different. However, the mathematics score did correlate with the normalized learning gain. Similar results were obtained in the research from University of New England (Buick, 2007).

Kim and Pak reported that solving 300-2,900 quantitative problems did not help students comprehend physics concepts (Kim et al., 2002). On the other hand, the work by Turşucu and co-workers showed that students with pre-existing algebraic skills have an advantage in physics problem-solving (Turşucu et al., 2020).

Researchers from the University of Port Harcourt, Nigeria, studied the effect of the instructional strategies, gender, and mathematics abilities of 200 students in senior secondary school on the normalized learning gain (Charles-Ogan et al., 2017). They found that there were significant correlations between instructional strategy and gain, and between mathematical ability and the normalized learning gain.

To gain more insight into the correlation of students' mathematical skills with their learning of physics, one may try to investigate the students' reasoning processes during problem solving. Yeatts and Hundhausen (Yeatts et al., 1992) reported that students struggled at transferring their knowledge from calculus to physics. The researchers from Kansas State University also investigated the students' knowledge transfer from calculus to physics by asking the students to solve electromagnetic problems that require calculus operation and describe what steps they made (Cui, 2006). They found that, although students were able to solve calculus problems, they were often unsure if they needed to apply calculus in a given problem. Later, from the same department, another group of researchers developed a so-called conceptual blending framework to investigate the student deficiencies when they solved electromagnetic problems (Hu et al., 2013). It was discovered that students were unable to blend their mathematics and physics knowledge to set up integrals. They discussed several types of so-called blends and possible strategies to change poor blends into productive blends. Additional work on students' difficulties in applying mathematics to physics has been done elsewhere (Nguyen et al., 2011a; Nguyen et al., 2011b; Wilcox et al., 2013; Bollen et al., 2015).

1.2 The Outline of Thesis

The next parts of this thesis are organized as follows. In Chapter II and III, we report the results and discussion of SUT students' performance on pre-instruction mathematics tests and their physics exams respectively. The results and discussion related to the correlation between the mathematics test scores and the physics exam scores are presented in Chapter IV. The conclusion is given in Chapter V. We provide all the questions of the mathematics tests and physics exam in the Appendix.

1.3 Methodology

This thesis can be divided into 4 steps.

1.3.1 Estimate the Validity and Reliability of the Exams

The results from the exams will be taken seriously if and only if the exams is valid and reliable. The validity and reliability of the mathematics tests physics exams will be mentioned in Chapter III and Chapter IV respectively.

1.3.2 Categorize the Exam

Mathematics tests will be categorized into 3 categories including algebra, geometry, and calculus. This categorization for each item is judged by the experts, the researchers. Physics exams will be categorized into 11 categories based on the lesson in class.

1.3.3 Analyze the Students' Performance

To analyze the students' performance, the average score of the students in both trimesters will be compared category wise.

1.3.4 Calculate the Pairwise Correlation between Categories

The correlation between mathematics and physics categories will be calculated using Pearson's product moment correlation. The correlation will be mentioned in Chapter V.