Using Mathematics Review to Enhance Problem Solving Skills in General Physics Classes

Sunil Dehipawala, Vazgen Shekoyan, and Haishen Yao

Abstract— **Mastery in basic arithmetic, algebra, and trigonometry is necessary to perform well in physics courses. In this project we studied the effect of pre-exposure to basic mathematical skills on problem solving ability, learning attitudes and math anxieties in general physics classes. Two sections of the same physics course were taught by the same instructor. Students in one section received 10-15 minutes intensive review on mathematics before regular physics lecture. The other group was given a full 50 minute physics lesson. Both groups were taught same physics concepts each day. The first group received less time for the traditional "physics" lesson, but got time to review and polish essential mathematical skills. The other group did not receive a formal mathematics lesson before the traditional physics lesson and hence got more time to discuss, listen, and ask questions. Course objectives of both groups were assessed by the same quizzes, exams, and surveys. At the end of the semester the problem solving skills of both groups were compared to determine whether having mathematics instructions before a physics lesson can help improve problem solving skills of students taking physics. According to the results of this study introduction of mathematics review at the beginning of the class can help students improve their problem solving skills in physics**

Index Terms—**Physics Education, Mathematics. General Physics, Engineering Technology**

I. Introduction

THE complete understanding of college physics principles and concepts require strong skills in algebra and some trigonometry. However, many students struggle with algebra-based introductory physics courses despite completing college algebra before taking physics. Even if the necessary pre-requisite courses in mathematics were completed, students were not able to perform simple math operations in physics classes. Many studies appear to show that knowledge of mathematics is positively correlated to success in introductory college physics courses[1-3]. Some studies have found that students who perform better on the mathematics portion of college entrance examinations receive better grades on their physics courses[4-5]. Many other studies have found positive correlations between the scores of mathematics pre-tests administered at the beginning of physics courses and the grades received in those physics courses[6-16]. These pre-tests contained basic algebra and trigonometry problems. However, the correlation coefficient varied widely with different student groups. Using gender as an example, one study found that the overall correlation between pre-test scores in algebra and physics grades for males is not as significant as the correlation found amongst female students[14]. All of the studies mentioned here have found some correlation between physics performance and mathematics skills. In those studies performance in physics was measured using the grade of a single test or the mean grade of several tests.

According to these cited works, a strong performance in a physics course depended on mathematical skills that were measured prior to taking the physics course. If a student has completed the prerequisites required for the physics course long before taking physics and lacks skills necessary for the physics course, the successful performance of that student in the physics course is doubtful. Performance in physics courses greatly depends on students' skill level of mathematics. Sometimes, they apply correct physics principles to a problem but are unable to continue the solution because of poor mathematics training. Since mathematical skills are essential for physics problem solving we have investigated a new method of physics teaching: providing and reviewing essential mathematics everyday just before starting the physics lecture component of the course. Subsequently, a comparison of their performance to another group of students, taking the same physics course but without a math review at the beginning can give an idea of the effectiveness of this technique.

Methods:

The Queensborough Community College General Physics 201 class mainly covers various topics of Mechanics such as Newton's laws, momentum, energy, rotational motion, gravity and fluid motion. This algebra-based physics course is required for engineering technology and computer technology students to fulfill their curriculum requirements. It has a college-level algebra and trigonometry course (MA 114 or MA 119) as a prerequisite (or a satisfactory score on the college mathematics placement test). The course consisted of 3 class hours, 1 recitation hour and 2 laboratory hours (4 credits).

The study population consisted of two Physics 201 sections approximately 24 students each during the Fall, 2013 semester. Both sections meet 3 times per week for 50 minute lecture, and once a week 2 hour lab plus 1 hour recitation.

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Lab and recitation classes were taught by different instructors. But during the recitation hour both student groups practice same problems assigned by the lecture instructor. Throughout the semester one section of the Physics 201 course received 10-15 minutes long intensive review on mathematics before covering the usual lecture material on physics. That section served as the experimental group. The mathematics portion was designed to give students brief review and practice so that they can effectively employ the mathematical concepts and methods in the physics course. Students worked in groups of 2-3 students on specially designed mathematical exercises to suite physics problem solving. The other section (the control group) utilized full class period of 50 minutes for traditional lecture on physics. During a class period both sections covered same amount of study material in physics and were introduced to same examples. To compensate for the time used for mathematical review at the beginning of the lecture, mathematical portions of the example physics problems were not solved completely during the class period in the experimental section. Instead they were briefly discussed, and the instructor suggested students to complete calculations at a later time on their own. The control class was introduced to the same physics examples, and the mathematics portions were explained along with physics as required.

The primary dependent variables were the scores students received for quizzes and exams administered throughout the semester. Other dependent variables included student survey responses concerning the study, given at the beginning and at the end of the semester. A diagnostic examination was given to both student groups at the beginning of the semester to compare their competency in mathematics. The diagnostic examination consisted of multiple choice problems/questions from all areas of MA 114 course (College Algebra and Trigonometry for technical students) which is a pre-requisite course for the Physics 201. Even though all Physics 201 students have taken MA 114, MA 119 or an equivalent course before registering for Physics 201, their preparation in mathematical skills may not be same. Some may have taken MA 114 and MA 119 several semesters earlier and lack the necessary skills to perform mathematical functions in physics. It is possible that some students lack the knowledge to employ mathematical resources they already possessed in the physics content. It is possible that some students have completed a physics course in high school and so may perform better regardless of instruction method. To eliminate this potential discrepancy between students, a baseline pre-test in physics was given at the beginning of the course. The analysis of pre-test results helped us to establish whether we had equivalent groups at the start of the semester.

Students in both sections were taught the course using the same syllabus and covering the same physics topics each day by the same instructor. To eliminate possible research bias the same quiz and test questions were given to both sections of the course. Also, all quiz and test questions were prepared for both groups based on same study guides and course syllabus.

Tests and Data collection:

1. Diagnostics Mathematics examinations were given to all students participating in the study.
2. Pre-tests and post-tests were administered to both sections of PH201 classes at the beginning and at the end of the semester.
3. Several mid semester exams and quizzes were given to all students.
4. The same final examinations, aimed at assessing the achievement of an appropriate content knowledge, were given to students in both sections. The final examination was used to verify the level of knowledge achieved at the end of the semester. The final examination was cumulative and covered all the topics of the physics course.

Table 1: Individual grades of preliminary math and physics tests. Group A- Experimental group; Group B- Control group

Preliminary math test grades		Preliminary Physics test grades	
Group A	Group B	Group A	Group B
10	15	0	0
15	15	0	0
15	20	0	0
20	20	0	0
20	25	0	0
20	25	0	0
25	25	0	0
25	25	0	0
30	27	0	0
30	27	0	0
32	30	0	0
32	30	0	0
33	30	0	20
35	35	20	20
40	40	20	20
45	45	20	20
47	47	20	20
50	50	20	20
55	60	20	20
65	75	20	20
70	75	20	25
95	80	25	25
100	94	25	25

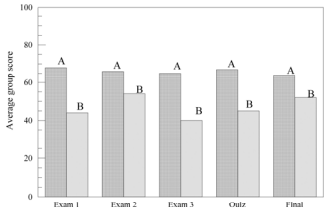
The analysis of results will provide an indication of the effectiveness of two different approaches of teaching physics.

Results and discussion:

Both experimental and control sections of the course were given same preliminary mathematics test on the first day of the physics class to gauge their ability to solve simple algebra and trigonometry problems. The test composed of 10 problems (each with several different parts). Problems were designed based on MA 114 and MA 119 course material that were pre-requisite mathematics courses for the physics course. Tests from both sections were graded with same rubric.

All students' individual grades are shown in first two columns of Table 1. Group A is the experimental group which received 10-15 minute math instruction each day before physics lessons. Group B is the control group. This group received traditional physics lecture during the whole period. According to the preliminary math test results, initial mathematical preparation is almost same for both groups. The average math scores were 42.0% for group A and 42.3% for group B. Only four students received 65% or higher grade in both groups. Majority of students showed lack of mastery of basic algebra or trigonometry necessary for the physics course. Columns 3 and 4 of Table 1 show all students' grades on the preliminary physics test. This test was given to measure any initial physics problem solving skills students had before taking the course. Both groups were given the same test and were graded using same rubric. In both groups more than half of the students couldn't do any part of a problem and their grade was recorded as 0%. Eight students from each group received grade of 20% and two of the students in group A and 4 students in group B received 25%. None of the students from any group was able to score more than 25%. The average scores in preliminary physics tests were 9.8% and 10.8% for groups A and B, respectively. Based on the preliminary math and physics tests, initial preparation of both groups was nearly identical.

Throughout the semester problem solving skills of both groups of students were assessed by several weekly quizzes, 3 exams, and a final exam. All of the exams and quizzes open-ended type problems in which students had to identify the physics concepts associated with problems, set up equations and solve equations to get final answer. Problems from both groups were graded with same rubric.



A-Experimental group
B-Control group

Figure1: Average exam and quiz grades of two sections of a physics course

Average exam grades and average quiz grades are shown in Figure 1. As revealed in this figure, on average, the experimental group (group A) performed significantly better than the control group (group B). Even though the students in the experimental group lost 10-15 minutes of physics lecture time for the mathematical review, they managed to score better than students who had full 50 minute Physics lecture in all 4 exams.

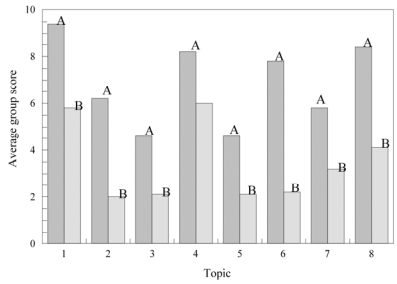


Figure 2: Average score on different topics.
A = Experimental group
B = Control group

1. 1-D motion, distance Va displacement, Speed Vs Velocity, uniform acceleration, Free fall motion.
2. 2D motion, Projectile motion.
3. Newton's laws, Friction
4. Circular motion, Newton's law of Gravitation
5. Conservation of momentum, Impulse
6. Fluid motion, Archimedes principle, Buoyancy
7. Work, Energy, Conservation of energy
8. Rotational Equilibrium.

The performance of students on several topics covered in the final exam is shown in Figure 2. Each problem could have earned a maximum of 10 points. The full solution of the problems consists of identifying the physics concept, setting up correct equations, solving for the required unknown, and obtaining the correct final answer with units. It is evident from Figure 2 that the students in the experimental group solved physics problems more accurately than the control group students in all of the 8 topics covered on the final exam.

Conclusion:

Based on our results it is clear that reviewing mathematics every day as a part of physics lecture may enhance problem solving skills of physics students with poor preparation in basic mathematical skills. This approach suggests the necessity of reviewing basic algebra and trigonometry as a part of a physics lecture to improve students' problem solving skills.

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