Integration of Math, Physics and Engineering, A Pilot Study for Success

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Abstract

The inherent integration between mathematics, physics, and engineering is obvious to experienced engineers and faculty, however, many incoming students find it difficult to see the connections. During the 1999-2000 academic year, a pilot study was conducted at Michigan Technological University to determine the effect of cohort scheduling students into integrated sections of calculus, physics, and first year engineering courses. Calculus-ready students were randomly selected and asked to participate in this study. Those declining our offer were used as our comparison group. The comparison and the test groups had similar compositions of majors, SAT/ ACT scores, and high school backgrounds. The results from this study show that the students in the test group scored significantly higher on common exams than did students in the comparison group. Follow-up analysis shows that the students in the test group continue to have higher overall grade point averages, and self-report a higher level of academic confidence that do their peers in the comparison group. This paper details the integration process, including the active collaborative teaching/learning styles used in the engineering courses, and recommends strategies for crossing the boundaries between departments and colleges.

Introduction

In the fall of 2000 Michigan Technological University switched to a common first year for entering engineering students. During the 1999-2000 academic year, in preparation for the common first year engineering program (1), two pilot courses were developed and delivered. In these courses students were taught computer and technical writing skills along with an introduction to the engineering profession. This was done in an active, collaborative learning environment. The students in the pilot group were also “cohort” scheduled in pilot sections of Calculus and Physics to facilitate and help demonstrate the integration between science, math, and engineering

Our goals for this program were threefold: 1) to learn how to integrate these three subjects such that students would recognize the importance of math and physics to engineering, 2) to apply active, collaborative learning/teaching and develop methods which would be incorporated into the common first year engineering program, 3) to assess the learning outcome effects of course integration and cohort scheduling.

Pilot Program Structure

To learn how to include and implement active collaborative learning and course integration in our pilot program, we needed to select students to participate in it. We also needed some method to assess our pilot course. Our selection process was to determine which entering freshmen students were calculus ready (i.e: those students with a Math ACT of 26 or higher) and were enrolled in these participating departments: Electrical, Civil, Environmental, Computer, Mining or Materials Engineering. From this population of 94 students, we randomly selected 47 students. The remaining 47 would become the comparison group. The students selected for the pilot courses were sent letters asking them to participate in the program. Out of this group, 31 students elected to participate. To ensure that the two groups were academically similar when entering MTU, we compared the Math ACT scores. The pilot group had a slightly lower average ACT of 30.5 than the comparison group (31.1).

The pilot program consisted of the courses shown in Table 1. To encourage and develop teamworking skills, students were assigned to four person teams in their Engineering, Calculus and Introductory Physics courses. Similar teams were used in the Physics Lab. Due to the number of seats available in the Physics Lab and a team size of 3, some team rearranging was required. The teams were rearranged each academic quarter.

Table 1: Freshman Engineering Pilot Program Courses

Fall Term	Credits	Winter Term	Credits
Engineering Fundamentals I (GN190)	4	Engineering Fundamentals II (GN290)	3
Calculus I (MA160)	4	Calculus II (MA161)	4
Physics Lab I (PH181)	1	Physics I (PH204)	4

The topics for the cohorted courses were typical of what one might expect in any first year engineering program. The engineering course (GN190) focussed on the fundamentals of technical writing (memos reports, executive summaries), the engineering disciplines, basic computer skills (both UNIX and PC systems), problems solving, data collection/analysis, reverse engineering/ mechanical dissection, and teaming. The calculus course (MA160) focussed on the development of calculus theory, differentiation, and introduction to integration. The physics course, in this case the physics lab, focused on discovery based learning. Theory of kinematics was not taught, but experiments were developed to help the students develop an understanding of the laws of motion (the theory was covered the following quarter). The key to this pilot study was the integration of these topics. This was facilitated by the incorporation of engineering examples in the calculus class, calculus homework problems were found in the engineering class and on engineering exams, and physics lab data was used in both math and engineering. One example of integration/ collaboration came with the assigning of a design project. The assignment was to analyze traffic flow in a small urban environment. The mathematics portion focused on data collection, and integration and differentiation of the data. The engineering focused on decision making, how to make measurements, where to make them, for how long, the decision making process, reports, and presentations. Outside experts were brought in to serve as resources for the students. Presentations where given in both the engineering class and math class, and reports were submitted to each instructor.

In the second quarter of this pilot program, students were enrolled in Physics I (PH204), Calculus II (MA161) and Engineering Fundamentals II (GN290). During this term, students learned about fundamental theories of physics, continued their Calculus sequence and were introduced to algorithmic thinking and computer programming. The students continued to develop their technical communication skills through mini-presentations and their technical writing skills through design project progress reports. Once again, students were required to integrate their knowledge between the courses. In this study, we promoted the integration by including integrated exam problems between the three courses. Integration was also encouraged in the term project that required an understanding of calculus to complete the design.

Academic Performance and Observations

Throughout the two quarters, we completed comparisons between the pilot (31 students) and comparison (63 students) groups. We found that the average GPA for students in the integrated program was significantly higher than the GPA of students in the non-integrated program. The pilot students had an average GPA that was 6% higher than the comparison group. This finding can be attributed to the academic performance in the integrated courses. For MA160, the students in the pilot study out-performed the comparison group by 20%. This difference decreased to 10% in MA161. The pilot students also out-performed the comparison group by 3% in the engineering courses. Table 2 shows the average grade received for the two groups based on a 100 point scale.

Table 2: Academic Performance Comparison between Pilot (31 students) and Comparison (63 students) Groups (100 point grade scale)

Course	Pilot	Comparison
Engineering Fundamentals I (GN190/GN120)	89.75	85.75
Calculus I (MA160)	91.25	75.50
Calculus II (MA161)	79.00	71.75
Physics I Lab (PH181)	83.25	84.00
Physics I (PH204)	72.50	69.50
Overall GPA	80.50	76.00

We attribute the better academic performance of the pilot group to the development of a learning community that was due in part to the cohorted courses and active, collaborative learning environment used in the engineering and calculus courses. Physics I Lab and Physics I were the only courses where the pilot and comparison groups performed similarly. At first, these results surprised us. Then we began to investigate why this could have occurred. Due to the classroom and team sizes for the Physics Lab, the pilot students were mixed in with other freshman students. Therefore, some of the teaming advantages were lost. When the pilot students took Physics I, a conventional lecture approach was used. Therefore, the pilot students did not have an active, collaborative learning environment.

In addition to the course performance differences between the pilot and comparison groups, we found that the pilot students remaining in engineering at MTU were on track for graduating in 4 years. "On-track" refers to the successful completion of one term of chemistry, one term of physics and three terms of calculus or credit for those courses. In the pilot group, 28 students out of 30 are on-track for graduating in four years. The opposite occurred in the comparison group. Almost 40% of these students were behind in their course completion.

During this two term program, we made several informal observations. Because students were enrolled in cohorted courses, the instructors for the courses met weekly to discuss how the classes were going and what material would be covered during the next week. In addition, and not by design, we began to discuss the students and their performance in the courses. We saw that some students were having trouble in all their cohorted courses. When this occurred, each instructor would meet with the student outside of class. After we did this a few times, we noticed that the students began to be better prepared for class. We also saw that the class dynamic began to change. Students began to ask us questions about engineering and how to plan their academic career. Several students told us that they were surprised that the instructors communicated with each other regarding class topics and student performance.

Student Self-Assessment

In December 2000, we surveyed the students in the pilot study and the comparison group regarding how they perceived their performance in engineering school and how the skills they learned in their first year were being used in their sophomore year. Out of the 94 surveys e-mailed to students, 45 responses were obtained. In the pilot course (GN190/GN290), 73% of the students responded to the survey, while only 34% of the students in the comparison group responded. A summary of the results are given in Table 3. Overall, one third of the students reported that teams helped them achieve a new level of understanding. Also, 53% of the students said that the integration of math, science and engineering courses was important and 20% were neutral.

The importance of teams was emphasized in the first year engineering program for both groups. Students recognized this because 95.7% and 64.4%, pilot and comparison groups, respectively, self-reported that teaming instruction was received in class. The pilot students (82.6%) reported that they had many team activities in their cohorted courses, while only half of the students in the comparison group reported that several teaming activities occurred in their freshman courses.

We asked students if they felt that their freshmen engineering courses gave them an advantage over other engineering students at MTU. Almost 40% of the pilot students and 23% of the comparison group felt that they had an advantage. Also, 30% of the pilot students and 68% of the comparison group responded that they had no advantage over other students. This implies that the students in the pilot group did perceive that the cohorted/integrated program did give them additional, useful coursework/skills.

The largest difference in student reporting between the pilot and the comparison groups occurred when we asked them if they knew the other students in their first year classes. The majority (65.2%) of students in the pilot program reported that they knew the names of most of their classmates, while half of the respondents in the comparison group reported that they only recognized a few of the students in their classes. To us, this implies that integrated classes that include teaming create an active learning environment.

Table 3: Student Survey Responses for the Pilot and Comparison Groups

Description	Pilot	Comparison
Teaming Instruction	95.7%	64.4%
Teaming Activities several times a week	82.6%	55.6%
Advantage over other students due to freshman classes	39.1%	22.7%
No advantage over other students due to freshman classes	30.4%	68.2%
Knew most of the students in classes by name	65.2%	0%
Recognized a few people in classes	17.4%	50%

Conclusions

During the pilot program completed in the 1999-2000 academic year, we found that the students in the pilot program out-performed the students in the comparison group. Not only did the pilot program students out-perform, they self-reported that they learned and developed teaming skills. These skills gave them a perceived advantage over other students. Also, due to the cohorted and integrated classes, they created a learning environment where they knew most of the students in their classes.

An interesting follow-up observation has been made regarding the students in our pilot study group. Many of them still choose to schedule themselves into the courses and sections together. Many have also chosen to continue their study groups and meet outside of class for social gatherings. This is a testament of the development of a true community. We will continue to follow these students to extract retention and educational performance data.

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