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# Enhancing students' achievement and self-assessed learning outcomes through collaborative learning strategies in various engineering courses

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ABSTRACT: This study was undertaken to establish the effectiveness of collaborative learning strategies in enhancing students' achievement and learning outcomes in three general engineering courses. The pre-test/post-test control group experimental design was used in the study. The experiment was conducted for a period of six weeks, with three experimental groups and three control groups involved in the study. Significant differences were obtained from the post-test achievement scores of the respondents, with the experimental groups engaged in collaborative learning scoring significantly higher than their control group counterparts, who were taught with the traditional lecture-discussion and individual learning methods. In addition, self-assessed learning outcomes were given by the respondents at the end of the experiment, and the groups engaged in collaborative learning were able to attain significantly better learning outcomes than the lecture groups in the areas of collaborative learning, problem-solving, feedback, interaction with peers, group skills, problem-solving skills and communication skills. Effect sizes were also positive for students involved in collaborative learning, meaning that they were able to achieve higher and attain better learning outcomes than the lecture groups in terms of percentile points.

Keywords: Collaborative learning, achievement, learning outcomes, engineering courses, experimental design

## INTRODUCTION

Engineering education in the 21st Century brings forth a multitude of challenges both in teaching and learning. Though many educators find the traditional lecture method effective in delivering lessons at the college level, it is still noteworthy to point out that teaching strategies must also evolve as the type of students at university change. A common observation is that attention span of students is just roughly 10 minutes [1], so engaging students in a 55-minute lecture by the professor is certainly futile in establishing retention and students' ability to think critically. To keep students engaged in learning throughout the hour, it is important to involve them in learning activities that allow them to participate in their own learning processes, thus allowing them to interact and communicate what they know at the moment and think of what they still want to know.

In the engineering classroom, however, the professor is often observed to use teacher-centred approaches like lecture and demonstration, often using deductive processes in teaching technicalities. But no matter how well prepared or how well scripted, delivering lessons through teacher-centred approaches is not an effective way of developing either knowledge or understanding [2]. Neither active learners nor reflective thinkers learn effectively in a class in which students are passive recipients of knowledge. Unfortunately, most engineering classes are taught with this traditional approach [3].

Prior studies in engineering education have found that progressive teaching styles involving student interaction that encourages exchange of ideas help improve their understanding of ideas, and in turn, their success in the course [4]. It is imperative, therefore, that engineering professors engage their students in active learning. There are indications that engineers are more likely to be active than reflective learners, with similar cognitive processes as extroverts and kinaesthetic learners [3]. Active learners do not learn much in situations in which they are passive recipients of knowledge (such as in most lectures); active learners work well in groups and tend to be experimentalists [3].

### Collaborative Learning

One effective learning strategy for active learners at the college level is collaborative learning. *Collaborative learning is a collective term for various educational approaches involving joint intellectual effort by students, or students and teachers together, where students work in groups of two or more, mutually searching for understanding, solutions, or meanings, or creating a product* [5]. Collaborative learning is a student-centred approach in that it allows the students to construct their own learning - through meaningful group processes. Aside from addressing the learning processes of engineering students, collaborative learning enables students to develop their abilities in working in teams. Now more than ever, engineers are expected to work on projects that put together a balanced use of technical, communication and people skills.

The idea of collaborative work is inseparable from engineering practice. In this sense, collaborative learning improves not only academic achievement of students, but also encourages the attainment of goals through enhanced group processes [6]. Appeals for engineering educational reform assert that graduates lack the necessary training and experience in solving unstructured problems, working in teams, and communicating effectively with engineers and other professionals; hence, collaborative learning is indispensable in preparing engineering students for their future careers [7].

Few studies show evidence of collaborative learning in engineering education in the Philippines, although collaboration is an ABET accreditation requirement of the engineering curriculum [6][8][9]. However, collaborative learning activities are viewed by some educators as impractical in the classroom or as an ABET accreditation requirement that must be superficially met [8]. In line with these results, a study on the effectiveness of active learning found that there is broad, but uneven, support for the core elements of active, collaborative, cooperative and problem-based learning in engineering education [10]. Indeed, ABET now requires institutional outcomes to produce graduates that demonstrate 11 competencies, including the abilities: *d. to function in multidisciplinary teams*, *e. to identify, formulate, and solve engineering problems, g. to communicate effectively* and *i. a recognition of the need for, and an ability to engage in life-long learning* [11]. Although academic institutions have a common understanding of the competencies that need to be achieved, still a vague consensus exists on how to enable students to achieve these ends. It is a common belief, however, that active learner-centred strategies have the ability to produce better student outcomes than traditional teaching strategies [2][7][9].

The intention of this study was to determine the effectiveness of collaborative learning in improving students' achievement, enhancing their learning outcomes, and at the same time develop other competencies required in the ABET, at least for three general engineering courses namely - differential equations, engineering economy and engineering management. Another objective of the study was to prove that collaborative learning strategies are applicable not only to design or capstone courses, but to all courses of varying content. Specifically, this study addressed the following questions:

1. Is there a significant difference in the pre-test and post-test achievement scores of the students in the experimental and control groups for the three courses?

   Hypothesis: there is a significant difference in the achievement scores of students in the experimental and control groups for the three courses.

2. What are the effect sizes of the mean achievement scores of the experimental and control groups for the three courses?

3. Is there a significant difference in the attainment of student outcomes in the experimental and control groups for differential equations, engineering economy and engineering management under the following learning areas: collaborative learning, problem-solving activities, feedback, interaction with faculty/peers, problem-solving skills, communication skills and group skills?

   Hypothesis: there is a significant difference in the attainment of student outcomes in the experimental and control groups for the three courses.

4. What are the effect sizes of the attainment of student outcomes for the experimental and control groups for the three courses?

## METHOD

This study made use of the pre-test/post-test control group experimental research design. The respondents of the study were 287 students (148 students for the control group and 139 students for the experimental group) enrolled in the six classes of engineering economy, differential equations and engineering management handled by this researcher. These three courses have been selected due to the multidisciplinary, heterogeneous grouping of students in each class and the varying course contents. The experiment was conducted during the preliminary term of the first semester of 2016-17 academic year in the School of Engineering and Architecture at Saint Louis University.

The activities used in engaging collaborative learning techniques in this study are based on the framework in *Learning together and alone*, which involved the following steps: a) make a number of pre-instructional decisions; b) explain the task and the positive interdependence; c) monitor students' learning and intervene within the groups to provide task assistance or to increase students' interpersonal and group skills; and d) assess students' learning and help students process how well their groups functioned [12].

The main instrument used to measure achievement of the students both in the pre-test and post-test was an achievement test that covered all topics in the prelim period (six weeks). A table of specifications was constructed for content validity of the test, and was constructed at the 50% level of difficulty. Reliability of the tests was computed using Kuder-Richardson 20, and revealed a 0.82, 0.76 and 0.89 reliability coefficient for differential equations, engineering economy and engineering management, respectively. Both the pre-test and post-test for differential equations were worth 60 points, for engineering economy - 100 points and for engineering management - 50 points.

The instrument used to measure students' self-assessed learning outcomes was derived from a questionnaire that measured students' self-reported learning gains [9]. The questionnaire was mainly designed to measure ABET's required student outcomes on graduates' abilities: *d. to function on multidisciplinary teams, e. to identify, formulate, and solve engineering problems, g. to communicate effectively* and *i. a recognition of the need for, and an ability to engage in life-long learning* [11]. Some items from the original questionnaire have been modified to fit the characteristics of the courses being measured.

This questionnaire had two main parts - course characteristics and course-related gains. Part I, Course Characteristics, asked the student to assess how often the class engaged in the given classroom activities in terms of collaborative learning, problem-solving activities, feedback and interaction with faculty/peers. The response mode was in terms of a Likert scale, where students were asked to choose on a scale of 1 to 4, how often the student or his/her instructor engaged in the given instructional activities. Part II, Course-related Gains, asked the student to assess how much he/she was able to make progress in each of the given learning areas in terms of problem-solving skills, communication skills and group skills. The student was asked to indicate on a scale of 1 to 4, depending on how much progress he/she believed they had made in the given learning areas. Reliability of the questionnaire is 0.93 using split-half method.

Treatment of Data

To determine if there are significant differences between the pre-test and post-test scores of the experimental and control groups, the *t*-test at the 5% level of significance (1-tailed) was used [13]. Also, effect sizes were computed to determine the difference in percentile points between the mean of the experimental group and the mean of the control group (with this group's mean set at the 50th percentile). Effect sizes are calculated by taking the experimental group mean minus the control group mean divided by the control group's standard deviation. The resulting z-score is then used with a table of areas under the normal curve to estimate the percentile-point difference between the experimental and control group means with the control group mean defining the 50th percentile [9][14].

## RESULTS AND DISCUSSION

Table 1: Achievement of students in the pre-test.

| Respondents | | Mean | Standard deviation | Interpretation of mean | *t*-test (*p*-value) | Difference |
|---|---|---|---|---|---|---|
| Differential equations | Experimental group | 3.20 | 5.78 | Poor | 0.22 | Not significant |
| | Control group | 2.35 | 5.31 | Poor | | |
| Engineering economy | Experimental group | 1.30 | 2.43 | Poor | 0.35 | Not significant |
| | Control group | 1.50 | 2.90 | Poor | | |
| Engineering management | Experimental group | 2.90 | 2.31 | Poor | 0.19 | Not significant |
| | Control group | 3.25 | 3.15 | Poor | | |

As seen in the results of the pre-test, the achievement of students both in the experimental and control groups is *poor*, which shows that all groups had very little base knowledge on the topics before the conduct of the experiment. Only a few students were able to answer one or two questions from the test either by guessing (for engineering management) or by applying a formula recalled from basic engineering (for differential equations and engineering economy). In experimental studies, the presence of a pre-test and control group are necessary to serve as control for all sources of internal validity [15]. In this sense, whatever scores gained in the post-test can be attributed to the treatment, which is in this case, the method of teaching.

Table 2: Achievement of students in the post-test.

| Respondents | | Mean | Standard deviation | Interpretation of mean | *t*-test, 0.05 (*p*-value) | Effect size |
|---|---|---|---|---|---|---|
| Differential equations | Experimental group | 40.00 | 15.76 | Above average | 0.03 (S) | +32 (increase) |
| | Control group | 26.64 | 13.52 | Average | | |
| Engineering economy | Experimental group | 60.08 | 18.56 | Above average | 0.01 (S) | +19 (increase) |
| | Control group | 50.43 | 20.69 | Average | | |
| Engineering management | Experimental group | 38.95 | 5.70 | Above average | 0.00 (S) | +34 (increase) |
| | Control group | 30.94 | 10.40 | Average | | |

All differences in the post-test scores of the experimental and control groups for the three courses are significant. This is an indication that collaborative learning strategies were able to contribute to the bigger gain scores of the students from the pre-test to the post-test for the experimental groups. These results are backed-up by several pieces of research that have been conducted in engineering education.

A study on collaborative learning among engineering students confirmed that collaborative learning positively influences student achievement [8]. In this study, students' reported use of collaborative learning strategies and reported self-efficacy for learning course material showed positive correlation with their course grade. A series of studies conducted by Johnson and Johnson have consistently reported that cooperation has favourable effects on achievement and productivity, psychological health and self-esteem, inter-group attitudes and attitudes toward learning [12].

In a study on effects of small-group learning on undergraduates in science, technology, engineering and mathematics (STEM), results revealed that the main effect of small-group learning on achievement, persistence and attitudes among undergraduates in STEM was significant and positive [14]. In this sense, it was proven that collaborative learning strategies are instrumental in improving more significantly, the students' achievement in the three courses.

The effect size indicates the number of percentile points that the experimental group is above (+) or below (-) the control group, with the mean of the control group at the 50th percentile. This means that the students in the experimental group for differential equations were able to increase their achievement by 32% more than their control group counterparts.

In the same way, the experimental groups of engineering economy and engineering management students were able to increase their achievement by 19% and 34% more than their respective control groups. Some researchers also made use of effect sizes as a way to compare results of groups exposed to different methods of teaching. Positive effect sizes (increases) have been reported for teaching methods that use collaborative learning strategies as part of their class activities [9][14].

Part 1 of the student outcomes and activities survey constituted the students' self- assessment on how often they (or the instructor) were able to engage in collaborative and more active, creative learning activities in the course.

Table 3: Mean scores of frequency of learning opportunities.

| Course/classroom activities | Control groups | Experimental groups | *t*-test (*p*-value) | Significance (0.05) |
|---|---|---|---|---|
| 1. Differential equations | | | | |
| a) Collaborative learning | 3.16 | 3.44 | 8.29E-08 | S |
| b) Problem-solving activities | 3.09 | 3.25 | 0.075 | NS |
| c) Feedback | 2.67 | 2.89 | 0.006 | S |
| d) Interaction with faculty/peers | 2.48 | 2.97 | 6.35E-08 | S |
| 2. Engineering economy | | | | |
| a) Collaborative learning | 2.9 | 3.38 | 6.23E-19 | S |
| b) Problem-solving activities | 3.11 | 3.19 | 0.19 | NS |
| c) Feedback | 2.67 | 2.89 | 0.0002 | S |
| d) Interaction with faculty/peers | 2.49 | 2.97 | 5.25E-05 | S |
| 3. Engineering management | | | | |
| a) Collaborative learning | 2.92 | 3.14 | 1.45E-22 | S |
| b) Problem-solving activities | 2.92 | 3.02 | 0.0038 | S |
| c) Feedback | 2.66 | 2.86 | 3.43E-05 | S |
| d) Interaction with faculty/peers | 2.47 | 2.94 | 0.03 | S |

The results in Table 3 show that the students' self-assessment of their learning outcomes is numerically higher in the experimental groups in all learning areas for the three courses. This means that in the experimental groups, the students were able to engage in more activities that enhanced their collaborative learning, problem-solving, feedback and interaction/interpersonal skills.

There was no significant difference in the frequency of problem-solving for the two courses since the same problem sets were given by the faculty to both experimental and control groups. From the results presented, it is clear that students engaged in more active learning were able to accomplish more learning gains as compared to the groups engaged in traditional lecture-discussion methods.

From Table 4, it is clear that students from the experimental groups in the three courses were able to significantly achieve better learning gains than their control group counterparts. Students exposed to active learning strategies were able to participate more in their own learning; thus, were able to improve more on their problem-solving skills, communication skills and group skills. The results are consistent with the three courses even if their contents are not the same.

Table 4: Mean scores on attainment of learning outcomes.

| Course-related learning outcomes | Control groups | Experimental groups | *t*-test (*p*-value) | Significance (0.05) |
|---|---|---|---|---|
| 1. Differential equations | | | | |
| e) Problem-solving skills | 2.77 | 3.21 | 2.30e-11 | S |
| f) Communication skills | 2.77 | 3.1 | 6.70e-06 | S |
| g) Group skills | 2.96 | 3.25 | 1.16e-07 | S |
| 2. Engineering economy | | | | |
| e) Problem-solving skills | 2.72 | 3.1 | 4.77e-06 | S |
| h) Communication skills | 2.79 | 2.98 | 1.60e-03 | S |
| i) Group skills | 3.01 | 3.22 | 8.80e-04 | S |
| 3. Engineering management | | | | |
| e) Problem-solving skills | 2.83 | 3.1 | 2.00e-02 | S |
| f) Communication skills | 2.85 | 3.38 | 3.45e-02 | S |
| g) Group skills | 2.89 | 3.94 | 4.90e-02 | S |

Table 5 below summarises the mean scores and effect sizes for the 34 items in the *Classroom activities and outcomes survey*.

Table 5: Overall effect sizes for learning outcomes.

| I. Classroom activities | Control group mean | Experimental group mean | Effect size |
|---|---|---|---|
| a) Collaborative learning | 3.05 | 3.47 | +19 |
| b) Problem-solving activities | 3.07 | 3.25 | +15 |
| c) Feedback | 2.70 | 2.94 | +12 |
| d) Interaction with faculty/peers | 2.55 | 2.88 | +15 |
| II. Course-related learning outcomes | | | |
| e) Problem-solving skills | 2.87 | 3.15 | +15 |
| f) Communication skills | 2.92 | 3.11 | +11 |
| g) Group skills | 3.10 | 3.28 | +9 |
| Overall | 2.92 | 3.20 | +14 |

The positive effect sizes for all 34 items and for all respondents surveyed in this experiment indicate that the experimental groups were able to engage in more active learning opportunities that enabled them to achieve better learning outcomes. The experimental groups engaged in collaborative learning were able to outperform the control groups in terms of collaborative learning activities, problem-solving activities, feedback, interaction with faculty/peers, problem-solving skills, communication skills, and group skills.

The results of this study are confirmed by studies in relation to engineering education. Results in these related studies indicate that active or collaborative methods produce both statistically significant and substantially greater gains in student learning than those associated with more traditional instructional methods [8][9][14]. It is, therefore, concluded at this point that engaging students in active and creative learning strategies, such as collaborative learning enables them to achieve greater learning gains not only in terms of grades, but also in terms of shaping their lifelong learning skills as the future builders of the nation.

## CONCLUSIONS

Collaborative learning is an effective strategy in improving students' achievement and attainment of learning outcomes, regardless of the nature and content of the course. It was proven in this study that collaborative learning is applicable not only in design or capstone courses, but even in general engineering courses with varied content and expected student outcomes.

It is recommended, therefore, to include collaborative learning as teaching-learning activities in the outcomes-based syllabus to enable the graduates of the engineering programmes to function in multidisciplinary teams, to identify, formulate and solve engineering problems, to communicate effectively, and to recognise the need for, and an ability to, engage in life-long learning.

Conducting further studies on collaborative learning on a larger scope is suggested, studies that cover courses across curricula, to further strengthen the inclusion of collaborative learning and other active learning strategies in the outcomes-based education system.

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BIOGRAPHY

Geraldine G. Nerona is a Professor of Industrial Engineering in the School of Engineering and Architecture at Saint Louis University, Baguio City, Philippines. After graduating with her Bachelor's degree at Saint Louis University in 1991, she worked as a production supervisor, then as an operations manager in two manufacturing companies. After working in the industry for five years, she found her home in teaching at her *alma mater* where she currently handles mathematics, industrial engineering, research, general engineering and some graduate studies. Because of her love for teaching, she pursued a Master's degree in education at the University of the Cordilleras in 2005 (*magna cum laude*) and was a board top-notcher for the licensure examination for teachers in 2002. She has been active in conducting research in engineering education and has been presenting her papers in the International Conference in Engineering Education since 2015. Aside from teaching, she is currently the extension programme coordinator of the Industrial Engineering Department, and as such, handles projects that involve extension services of the University to other organisations and communities.