Impact of Class Size on Student Perception of Learning and Learning Outcomes in Project-Based Learning

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Abstract

This research paper evaluates the influence of class size in a project-based learning course. The impact of the student-faculty ratio and the overall class size on the learning process has been discussed and debated in the pedagogical literature for many years.[1, 2] A significant number of these studies has been particularly limited to K-12 education, generating a passionate discussion on public policy and cost of education. There is relatively limited data on the impact of class size on undergraduate engineering education. This study investigates the influence of class size on the learning process by evaluating student perception of learning and the achievement of learning outcomes. Assessment data and an end-of-semester survey are used as the two main metrics. The investigation is carried out in a junior-level course focused on project-based learning (PBL). The course is mandatory for engineering and engineering technology majors. For this study, data from two sections of the course that were taught during Spring 2016 by the same instructor has been used. One of the sections consisted of 19 students while the other section had 32 students. However, the course content, teaching methodology, evaluation rubrics, project description, and multidisciplinary team composition were identical in both sections. All students in both sections were juniors, and had already taken two project-based courses at freshmen and sophomore levels. The student perception of learning has been evaluated by using the institutional procedure for the measurement of Student Assessment of Instruction (SAI). The learning outcomes have been directly assessed by using project reports, assignments, essays, etc. that were submitted by students in both sections throughout the semester. A preliminary evaluation of the data demonstrates that the student perception of learning is higher when the class size is smaller. Also, the performance indicators for learning outcomes indicate that the smaller section performs better. An outline of the study is provided in this paper along with a presentation of the data and some discussion on the impact of the study.

Keywords: Class size, Project-based learning, Learning outcomes.

1. Introduction

Class size is often reported as a significant variable that influences student learning.[2] While many small colleges and universities report a relatively small class size as an important attribute that enhances student engagement, larger universities find it unavoidable to increase class sizes, especially for introductory and freshmen level courses. Recent focus on online learning and hybrid teaching (combined online and classroom teaching) has revived the discussion on student-instructor ratios and the relevance of one-on-one interaction between faculty and students. The existing literature reports the significance of small class sizes for primary, middle and high school students.[3, 4] The literature attributes an improvement in cognitive and non-cognitive ability to relatively small class sizes.[4] It is, however, pointed out that reduction in class size needs to be coupled with the presence of a highly skilled instructor in order to observe measurable benefits in student performance.[5] The discussion on class size can often be contentious, especially in the context of public education and student performance. Some of the published literature even reports long-term effects of class sizes such as wages, success in pursuing higher education, etc.[4] There are studies that report a deterioration in the achievement of student outcomes with an increase in the class size, particularly in a public university environment.[6] It is readily acknowledged in the literature that findings about the class sizes can significantly vary with subject matter as well as student level. Although economy of scale is the main rationale for a large class size, it is generally argued that the benefits of such an increase start tapering off since increasing class sizes typically result in lower student retention, adverse student learning, etc. This study does not aim to discuss social issues or public policy, but the discussion in this study is limited to examining any measured influence of class size on the perceptions of learning and outcomes assessed at the end of the semester.

Project-based learning (PBL) is a recognized pedagogical approach that is commonly acknowledged to motivate students and enhance student engagement.[7,8] PBL allows an incorporation of open-ended projects into the curriculum that could have multiple solutions. A focus on projects allows the students to apply and integrate ideas while acknowledging technical and non-technical constraints. Student-instructor interaction is particularly important in a project-based learning environment where students are typically iterating through design, analysis and testing. An increase in the class size can directly result in a lower amount of time spent by the instructor with each team. Arguably, this can affect the timely feedback that is needed by the students, and this may in turn affect the successful completion of projects. It is commonly acknowledged that open-ended projects require intermittent intervention from the instructor to keep the student teams on track, to help students with specific technical challenges, and to resolve any issues with coordination between team members.

This paper evaluates the impact of class size on student perception of learning and the achievement of learning outcomes by comparing two sections of a project-based learning course. Although the class sizes compared in this study are not significantly different, it is important to note that most other variables such as class schedule, instructor style, nature of projects, etc. have been blocked. These variables have been blocked since the same instructor taught both sections and the two sections did not have any teaching assistants. Furthermore, both sections were scheduled for Tuesday and Thursday mornings and the same projects were assigned to the two sections. Many studies on class size compare very small classes to very large classes, but this study aims to determine whether a relatively small increase in class size (68% in this case) demonstrates any significant differences in student perceptions of learning and in the achievement of learning outcomes.

2. Project-based Learning Course

The project-based learning course that is discussed in this study is a junior-level course that aims to introduce students to engineering design and development and project management while working in interdisciplinary teams. Furthermore, this course is expected to serve as a preparation for the Senior Design (Capstone) course during the senior year. The course content and the main deliverables of the course are listed in Table 1.

Table 1. Course Content and Deliverables.

Week	Course Content	Student Deliverables
1	Project introduction, introduction to product development, team formation	
2	Engineering Project Management: Basic Concepts	Mini project
3	Engineering Project Management: Project Life Cycle and Management	Report – Mission Statement and Customer Needs
4	Global Aspects of Engineering Career (Guest Speaker)	Report – Target Specifications and Concept Sketches
5	Engineering Project Management: Analysis of Alternatives	
6	Engineering Project Management: Failure Mode and Effect Analysis (FMEA)	Report – Preliminary concept selection
7	Engineering Ethics (case studies and guest speaker)	Report – Final concept design and project schedule
8	Mid-term Project Presentation	Presentation – proof-of-concept
9	Professional Behavior (Guest Speaker)	Reflection on ethical behavior
10	Professional Development (Guest Speaker)	Reflection on professional behavior
11	Project work	Reflection on professional development; Report – Fabrication, Assembly, Testing
12	Engineering Ethics (Case Study)	
13	Project work	Reflection on technological impact on society
14	Project work	
15	Project work	Final Report and Final Project Demonstration

Students enrolled in this class could be majoring in technology or engineering programs (mechanical and electrical). Therefore, the emphasis of the content is on the design process and project management skills instead of specific component design. Students work in teams of four and every team consists of at least one electrical (technology or engineering) and one mechanical (technology or engineering) student. The course is worth three credits and the contact time is divided into two sessions of 100 minutes each, every week of the semester. One of the two sessions is used for team meetings and tasks related to the project. The instructor participates in the team meetings to provide feedback and resolve any problems among team members. The instructor also critically examines the design, project plan, analysis results, etc. every week during the team meetings. This provides essential feedback to the students during different phases of the project. These meetings also afford the instructor an opportunity to closely observe team dynamics and intervene, if necessary. All team members perform peer evaluations to assess the performance of other members two times during the semester. These peer evaluations are anonymously reported back to the students. For Spring 2016, the 2016 IEEE Southeast Conference Hardware Competition project was used as the course project and assigned to all the teams in both the sections. The main deliverables for this course in Spring 2016 were robot design and project demonstration at the end of the semester. Reports associated with the different phases of the project are required from the project teams. Reflection essays on some case studies are also required deliverables for this course, as listed in Table 1.

3. Data Collection and Results

This section discusses the results from an evaluation of student perception of learning when two sections of the course were presented in Spring 2016. The student perception of learning is measured through an end-of-semester survey that was completed by the students registered in these two sections. Learning outcomes are also assessed based on the multiple instruments used through the semester for data gathered from both sections. This data is presented and discussed in this section.

The data collection was performed in Spring 2016. From the larger section (Section A), 30 students (out of 32) responded to the survey. Only 10 students (out of 19) responded to the survey from the smaller section (Section B). Since the survey was part of the end-of-semester Student Assessment of Instruction (SAI), an Institutional Review Board (IRB) request for Human Subjects Research was not necessary. The survey was conducted in the electronic format only and students had access to the survey during the last four weeks of the semester. Students were asked to respond to the following statements in the survey:

1. The instructor explains the subject matter clearly.
2. The instructor answers questions appropriately.
3. The instructor stimulates my thinking.
4. The instructor motivates me to do my best work.
5. The instructor helps students sufficiently with course-related issues.
6. The instructor is regularly available for consultation.
7. The instructor provides feedback on my progress in the course on a regular basis.

Students can respond to the survey questions on a four point Likert scale (Strongly Agree, Agree, Disagree, Strongly Disagree). The questions in the survey are specifically aimed at comprehending the instructor’s availability to assist students with their projects. Multiple questions are asked to determine whether students are satisfied with receiving feedback on their projects in a timely manner. This is particularly relevant since the instructor’s engagement is extremely important in a project-based learning environment. All the survey responses are quantified using a 1-4 Likert scale, with 1 representing a strong disagreement with the survey statement and 4 representing a strong agreement with the survey statement. The 1-4 scale allows a quantitative analysis of the data in addition to a general subjective analysis of the responses obtained from the survey.

In addition to evaluating the student response to the survey, learning outcomes are separately assessed for the two sections. The learning outcomes are specifically broken down into performance criteria and evaluated by using student performance in assignments and projects. The following performance criteria were identified to evaluate the learning outcomes for this course:

1. The student shall be able to describe ethical issues that occur in the modern workplace.
2. The student shall be able to identify and describe several recent events, issues, or developments in engineering in regional, state, federal, or international settings.

3. The student shall be able to describe several professional development activities that will contribute to maintaining technical currency in the profession.
4. The student shall be able to identify and describe several recent events, issues, or developments in engineering in regional, state, federal, or international settings.

Table 2 summarizes the results from the student survey quantitatively by calculating the averages and standard deviations from student responses for each survey statement.

Table 2. Student Perception – survey results.

Survey questions	Larger section (Section A)	Smaller section (Section B)
1. The instructor explains the subject matter clearly.	3 (SD = 0.84)	3.5 (SD = 0.67)
2. The instructor answers questions appropriately.	3.4 (SD = 0.55)	3.6 (SD = 0.49)
3. The instructor stimulates my thinking.	3.2 (SD = 0.75)	3.6 (SD = 0.49)
4. The instructor motivates me to do my best work.	3.5 (SD = 0.56)	3.6 (SD = 0.66)
5. The instructor helps students sufficiently with course-related issues.	3.5 (SD = 0.56)	3.7 (SD = 0.46)
6. The instructor is regularly available for consultation.	3.5 (SD = 0.62)	3.6 (SD = 0.49)
7. The instructor provides feedback on my progress in the course on a regular basis.	3.4 (SD = 0.62)	3.6 (SD = 0.49)

The results in Table 2 indicate the average of student responses with an average of 1 indicating that the students strongly disagree with the survey statement and an average of 4 indicating that the students strongly agree with the survey statement. As can be seen from the results in Table 2, the average scores for Section B (smaller section) are relatively higher for all seven questions. The standard deviation (SD) for each question has also been shown in Table 2. It can be observed from the results in Table 2 that the standard deviations for the larger section (Section A) are generally higher, indicating a larger spread of the data. For two of the seven survey questions (# 1 and # 3), the student perception is much more positive for the smaller section. This can be concluded from a much higher mean and a much lower standard deviation for these two questions for Section B. No statistical analysis has been performed since the numbers for this study are low. Some of the qualitative statements from the smaller section provide further evidence in support of the student perceptions. A few examples of student statements (from the smaller section) are as follows: ‘the instructor provides feedback and uses a rubric to explain what is wrong with an assignment if there are shortcomings’, ‘the course’s main purpose was to give the students an opportunity to get used to group work, the course was successful in getting the team to iterate in order to solve problems’. From the larger section, some of the student statements are as follows: ‘more assistance could be provided with different aspects of the project’, ‘teams could stay on track if they are required to make demonstrations more often’. These statements further indicate that students from the smaller section had a more positive learning experience. It can be argued that student statements are direct implications of the student-faculty ratio even though the student numbers for this study are low.

The four performance criteria identified earlier in this section are evaluated in order to assess the learning outcomes for this course (as per the assessment map of the program). The evaluation of the performance criteria is based on identical rubrics that have been used for both sections. The rubrics have been developed such that the evaluation of student work is categorized as Excellent, Satisfactory, Marginal or Unsatisfactory. An example of two such rubrics is shown in Table 3.

Table 3. Evaluation rubrics – examples.

	Excellent (4)	Satisfactory (3)	Marginal (2)	Unsatisfactory (1)
Ethical behavior - reflection	reflection discusses possible ethical lapses and the importance of being alert to avoid such lapses; reflection discusses possible consequences of ethical lapses; reflection discusses the professional code of ethics; reflection discusses means of ensuring consistent ethical behavior	reflection discusses lapses and consequences; reflection mentions professional code of ethics and possible means of ensuring ethical conduct	reflection contains limited discussion on lapses; limited/no discussion on consequences; limited discussion on professional code of ethics	reflection does not contain much discussion on possible ethical lapses; no discussion on professional code of ethics; no discussion on consequences
Professional behavior - reflection	reflection discusses possible lapses and the importance of cultural sensitivity to develop professional relationships with diverse colleagues in a workplace; reflection discusses possible consequences of lapses and possible ways to avoid such lapses; reflection discusses means of ensuring consistent professional behavior	reflection discusses lapses and consequences of lapses; reflection mentions cultural sensitivity and the means by which one can ensure professional behavior	reflection contains limited discussion on lapses in professional behavior; limited/no discussion on legal and personal consequences; limited discussion on cultural sensitivity	reflection contains no discussion on possible lapses in professional behavior; no discussion on cultural sensitivity; no discussion on personal and legal consequences

The evaluation of performance criteria is quantified from 1 to 4, as shown in the rubrics in Table 3. The output from these evaluation rubrics is merged and used to calculate an indicator in order to assess the overall outcome. The averages from the evaluation of indicators in each section are listed in Table 4. A performance indicator can range from 1 (unsatisfactory) to 4 (excellent).

Table 4. Performance indicators – results.

Indicators	Larger section (Section A)	Smaller section (Section B)
1. The student shall be able to describe ethical issues that occur in the modern workplace.	3.30 (SD = 0.69)	3.41 (SD = 0.68)
2. The student shall be able to identify and describe several recent events, issues, or developments in engineering in regional, state, federal, or international settings.	3.12 (SD = 0.56)	3.37 (SD = 0.50)
3. The student shall be able to describe several professional development activities that will contribute to maintaining technical currency in the profession.	3.00 (SD = 0.40)	3.35 (SD = 0.63)
4. The student shall be able to identify and describe several recent events, issues, or developments in engineering in regional, state, federal, or international settings.	2.87 (SD = 0.76)	3.18 (SD = 0.83)

The quantification of the indicators is done such that an indicator of 3 or above means that the outcome has been successfully achieved. The numbers in Table 4 are averages computed from the evaluation of all the students in each section. As can be seen from the results in Table 4, the larger section (Section A) shows an average of less than 3 for criteria # 4. Overall, the smaller section consistently shows a higher average for each indicator. The standard deviation (SD) for each indicator is also listed in Table 4 to indicate the spread of the data. As can be seen, the SD from the two sections for each indicator is comparable. The calculated average of all indicators is higher for the smaller section (Section B), ranging from 3 to 11% higher.

4. Discussion and Conclusions

An investigation into the impact of class size has been carried out in this study. The study is limited to a project-based learning course for two sections of the course that are taught by the same instructor. The results of this study clearly indicate that the student perception of learning in the smaller section is more positive, as can be seen from the student response to all the survey questions. Also, the evaluation of learning outcomes through the indicators clearly demonstrates that all the outcomes are successfully achieved for the smaller section. Furthermore, all the indicators are relatively higher for the smaller section. Even though the class sizes compared in this study were not extremely different, it is important to note that the observations from this study are similar to other observations in the literature that generally compare very large classes to very small classes. The findings in this study are particularly relevant since the course investigated for class size is a project-based learning course that requires the instructor to specifically interact with each project team on a weekly basis. This student-faculty interaction is critical for the students in order to successfully complete their projects. The nature of the student-faculty interaction is different from a conventional lecture or a laboratory course where one-on-one interaction is not necessary during class time.

This study aims at initiating a discussion on the importance of student-faculty interaction in engineering education. Although there is a significant amount of policy discussion in K-12 education about the importance of small class sizes, there does not seem to be enough literature on student-faculty interaction in a highly technical area such as engineering. Since more and more universities are starting engineering programs due to a high demand for engineering graduates, it may be beneficial for administrators to have access to literature about recommended student-faculty ratios. Administrators may also benefit from a thorough discussion on the effect of class size on specific metrics such as learning outcomes, student retention, student satisfaction, etc. It is hoped that the framework proposed in this study can be used by other educators to evaluate the effect of class size.

This study has been limited to just two sections of a project-based learning course. Therefore, the findings of this study cannot be generalized in any way. Furthermore, the data collected in this study is limited and cannot be used to draw any broad statistical conclusions. In the future, this study will be extended by evaluating the effect of class size at different levels of student standing in order to comprehend whether the influence of class size is significantly different between freshmen and seniors. Also, the influence of class size on a project-based learning course will be compared with a lecture-based or a laboratory-based course in order to determine whether class size is more critical for specific types of courses. Furthermore, the study will be replicated with a larger number of data points to compare very small class sizes to significantly large ones.

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