Comparison of Faculty and Ph.D. Candidate-Instructed Capstone Senior Design Classes

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Abstract

This paper compares capstone senior design classes taught by faculty versus Ph.D. candidates. Traditionally, these classes were taught by capstone design faculty. Each class is unique. Alternately, these classes were taught by Ph.D. candidates under the guidance of one selected faculty. The trade-off could be the overall quality for the consistency across classes. To address this issue, the alignment of the instructor's teaching with the course learning objectives/outcome, the effectiveness of the instructor, the improvement of the student's knowledge of the subject and the excellence of the course were investigated. Faculty evaluations from Fall 2015 to Spring 2018 and Ph.D. candidates' evaluations in the academic year 2018-2019 were analyzed. The results showed that the Ph.D. candidates instructed the class as effectively as the faculty. However, their classes were perceived as of lesser quality than those taught by the faculty. The level of inconsistency across classes continues to exist.

Keywords

Senior design, faculty-instructed, graduate teaching assistant, teaching evaluation.

Introduction

The improvement of capstone senior design course has been a persistent process. Robert H. Todd, et al.[1] found that disciplines involving design and manufacture of products such as mechanical, industrial, manufacturing, and electrical engineering have placed high emphasis in design courses. The survey identified the importance of industry-sponsored projects, team work, course duration, course logistics, and requirements for project completion. These aspects were confirmed through literature[2] and an online survey[3]. Bob Bond found that capstone design course is more than finding a technical solution to a particular problem[4]. The non-technical aspects such as problem definition, project planning, design selection and optimization, team building, communication, presentation skills, interpersonal skills, meeting skills, and conflict resolution that make students better engineers. Teaching beliefs and practices of capstone design faculty were shifted to help students define the project scope and find knowledge to complete their work[5]. In addition to written and oral communication, engineering ethics and project management are also prominent topics. To assess senior design courses across engineering disciplines, Larry J. McKenzie pointed to Accreditation Board for Engineering and Technology (ABET) outcomes[6]. The outcomes with sufficient specificity enable fairly straightforward assessment. With this framework, the course can be revised to accommodate the rise in enrollment[7] and the preparation of students for the course can be implemented[8].

Mechanical engineering capstone senior design at NC State University is a one-semester course credited four hours. At minimum, there are two fall and four spring classes in an academic year. There are occasions when an extra fall and/or spring class be added. A typical senior design class has six teams, each composed of five members, working on an industry-sponsored project. In a team, manufacturing positions include one machinist, two shop fabricators and two welders; administrative positions include one captain, one company contact and one treasurer. The teams are graded on four presentations (Feasible Design Proposals, Feasibility Study Review, Critical Design Review and Detail Design Review), three cumulative reports and the prototype. In addition, each student is graded individually on feasible design and an inventor's notebook.

In the past, these classes were taught by designated faculty. Although a certain framework was laid out in the syllabus, the faculty taught his/her class in their own way. Naturally there exists inconsistency across classes. Starting Fall 2018, senior design classes were taught by Teaching Assistants (TA) requiring that they are Ph.D. candidates. The TAs are trained weekly by one selected faculty. All teaching materials, from lectures to grading rubric, are the same. With this practice, some consistency could be achieved.

Method

Upon completing a semester, the students evaluate several aspects of a class. The evaluation for each aspect ranges from 1 to 5, where 1 is strongly disagree, 2 is disagree, 3 is neutral, 4 is agree and 5 is strongly agree. While they reflect from the conduct of the professor to the value of the course material, four aspects that reflect the quality of the class are:

1. The instructor's teaching aligned with the course learning objectives/outcomes.
2. Overall, the instructor was an effective teacher.
3. This course improved my knowledge of the subject.
4. Overall, this course was excellent.

Aspects 2 and 4 conclude the overall quality of the faculty and the class while 1 and 3 give possible reasons contributing to the conclusions. For simplicity, these four aspects will be referred to as Teaching Alignment, Instructor Effectiveness, Knowledge Improvement and Course Excellence. Due to privacy, the true identity of the faculty and the TAs will be concealed. Instead, they will be referred to as faculty A, B, C, D and TAs A, B, C, D.

Let N_A, N_B, N_C, N_D be the number of classes taught by faculty A, B, C, D and $x_{A,j}$, $x_{B,j}$, $x_{C,j}$,, $x_{D,j}$, be the evaluations of faculty A, B, C, D for a given semester j. The evaluation averages for the faculty are

$$\bar{x}_A = \frac{1}{N_A}\sum_{j=1}^{N_A} x_{A,j}\ ,\ \bar{x}_B = \frac{1}{N_B}\sum_{j=1}^{N_B} x_{B,j}\ ,\ \bar{x}_C = \frac{1}{N_C}\sum_{j=1}^{N_C} x_{C,j} \text{ and } \bar{x}_D = \frac{1}{N_D}\sum_{j=1}^{N_D} x_{D,j}\ . \quad (1)$$

The consistency of an individual faculty can be seen through his/her standard deviation.

$$s_A = \sqrt{\frac{1}{N_A - 1}\sum_{j=1}^{N_A}\left(x_{A,j} - \bar{x}_A\right)^2}\ ,\ s_B = \sqrt{\frac{1}{N_B - 1}\sum_{j=1}^{N_B}\left(x_{B,j} - \bar{x}_B\right)^2}\ ,$$

$$s_C = \sqrt{\frac{1}{N_C - 1}\sum_{j=1}^{N_C}\left(x_{C,j} - \bar{x}_C\right)^2} \text{ and } s_D = \sqrt{\frac{1}{N_D - 1}\sum_{j=1}^{N_D}\left(x_{D,j} - \bar{x}_D\right)^2}\ . \quad (2)$$

Collectively, the departmental average and standard deviation are

$$\mu = \frac{1}{N_A + N_B + N_C + N_D}\left(\sum_{j=1}^{N_A} x_{A,j} + \sum_{j=1}^{N_B} x_{B,j} + \sum_{j=1}^{N_C} x_{C,j} + \sum_{j=1}^{N_D} x_{D,j}\right) \quad (3)$$

and

$$\sigma = \frac{1}{N_A + N_B + N_C + N_D - 1}\left[\sum_{j=1}^{N_A}\left(x_{A,j} - \mu\right)^2 + \sum_{j=1}^{N_B}\left(x_{B,j} - \mu\right)^2 + \sum_{j=1}^{N_C}\left(x_{C,j} - \mu\right)^2 + \sum_{j=1}^{N_D}\left(x_{D,j} - \mu\right)^2\right]. \quad (4)$$

For a given semester, if the senior design faculty were to continue teaching, the faculty average will have an expected value of

$$E(x) = \frac{1}{4}\left(\bar{x}_A + \bar{x}_B + \bar{x}_C + \bar{x}_D\right). \quad (5)$$

On the other hand, if the classes are taught by TAs A, B, C and D, the performance evaluations will be x_{PhDA}, x_{PhDB}, x_{PhDC}, x_{PhDD}. Their evaluations can be compared with the expected faculty average. The analysis is conducted for all four aspects - Teaching Alignment, Instructor Effectiveness, Knowledge Improvement and Course Excellence.

Results

Because curriculum changes over time and instructors tend to change how they deliver the course, the study for faculty was limited to the latest three academic years. In so doing, a large gap in sample size can also be avoided. Fifteen faculty-taught courses will be compared to five TA-taught courses. Table 1 shows the faculty's evaluation averages in four aspects from Fall 2015 to Spring 2018. Note that an evaluation of 4 represents "desirable." Faculty A did not meet the desirable evaluations in any aspect. Faculty B, C were desirable in all four aspects. Faculty D was clearly above desirable.

Table 1. Evaluation average and standard deviation for faculty from Fall 2015 to Spring 2018

	Classes Taught	Teaching Alignment	Instructor Effectiveness	Knowledge Improvement	Course Excellence
Faculty A	3	$\bar{x}_A = 3.77$ $s_A = 0.32$	$\bar{x}_A = 2.50$ $s_A = 0.26$	$\bar{x}_A = 3.40$ $s_A = 0.53$	$\bar{x}_A = 3.00$ $s_A = 0.61$
Faculty B	2	$\bar{x}_B = 4.05$ $s_B = 0.21$	$\bar{x}_B = 4.10$ $s_B = 0.0$	$\bar{x}_B = 4.15$ $s_B = 0.35$	$\bar{x}_B = 4.00$ $s_B = 0.57$
Faculty C	5	$\bar{x}_C = 4.20$ $s_C = 0.16$	$\bar{x}_C = 4.02$ $s_C = 0.22$	$\bar{x}_C = 4.20$ $s_C = 0.39$	$\bar{x}_C = 4.12$ $s_C = 0.23$
Faculty D	5	$\bar{x}_D = 4.44$ $s_D = 0.33$	$\bar{x}_D = 4.40$ $s_D = 0.27$	$\bar{x}_D = 4.44$ $s_D = 0.29$	$\bar{x}_D = 4.38$ $s_D = 0.33$
Department	15	$\mu = 4.17$ $\sigma = 0.35$	$\mu = 3.85$ $\sigma = 0.75$	$\mu = 4.11$ $\sigma = 0.52$	$\mu = 3.97$ $\sigma = 0.63$

The faculty's standard deviation or consistency was also measured. Consider Instructor Effectiveness which is the conclusion on the instructor, all faculty were relatively consistent. For Course Excellence which is the conclusion on the class, the rankings of consistency from least to most were faculty A, B, D and C.

As a department, the averages for Instructor Effectiveness (μ = 3.85) and Course Excellence (μ = 3.97) were bordering below desirable while for Teaching Alignment (μ = 4.17) and Knowledge Improvement (μ = 4.11) were above desirable.

Although it is sufficient to gauge the faculty evaluation to the desirable evaluation of 4, where the faculty stood within the department can also be shown. Figure 1 shows the faculty performance and consistency across classes using the departmental averages as standards. The evaluation averages for faculty A, B, C, D are shown in blue, purple, pink and green respectively while the departmental averages are shown in red. In all four aspects, faculty A performed below the departmental average. Other than slightly below the departmental average in Teaching Alignment, faculty B together with faculty C and D performed near or above the departmental average in Instructor Effectiveness, Knowledge Improvement and Course Excellence. Table 2 summarizes how far the faculty averages were from the departmental averages. It also shows the inconsistency between faculty A and D in Instructor Effectiveness and Course Excellence where they were 1.90 and 1.38 apart.

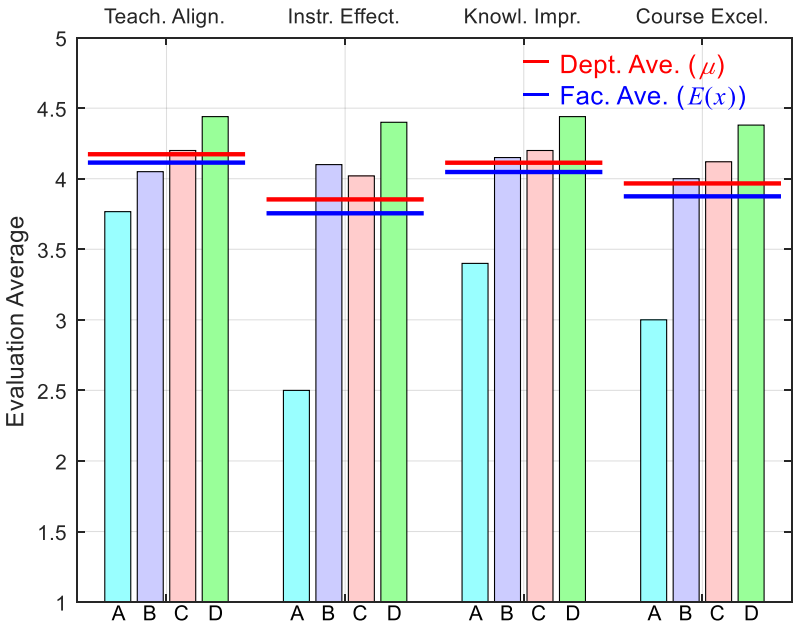

Figure 1. Performance of faculty from Fall 2015 to Spring 2018

Table 2. Faculty evaluation in comparison to departmental average from Fall 2015 to 2018

	Teaching Alignment	Instructor Effectiveness	Knowledge Improvement	Course Excellence
Faculty A	-0.41	-1.35	-0.71	-0.97
Faculty B	-0.12	0.25	0.04	0.03
Faculty C	0.03	0.17	0.09	0.15
Faculty D	0.27	0.55	0.33	0.41

If the same four faculty were to continue teaching classes, the expected evaluation average for a given semester would be $E(x)_{TA} = 4.11$ for Teaching Alignment, $E(x)_{IE} = 3.76$ for Instructor Effectiveness, $E(x)_{KI} = 4.05$ for Knowledge Improvement and $E(x)_{CE} = 3.88$ for Course Excellence. Note that the expected semester averages are slightly lower than the departmental averages as shown in Fig. 1 in navy blue.

In the alternative practice, a group of 4 Ph.D. candidates were trained by faculty D to instruct senior design classes. The evaluations for these TAs for the academic year 2018-2019 were recorded (Table 3).

Table 3. Evaluations for TAs in Academic Year 2018-2019

	Classes Taught	Teaching Alignment	Instructor Effectiveness	Knowledge Improvement	Course Excellence
Ph.D. A	1	3.6	3.1	3.3	2.4
Ph.D. B	1	3.5	3.6	2.7	2.5
Ph.D. C	2	4.5	4.3	3.6	3.6
		3.8	3.6	3.5	3.6
Ph.D. D	1	4.3	4.2	4	3.9

Similar to Fig. 1 but without the departmental averages, Figure 2 uses the faculty performance and the expected averages for a given semester for comparison. Overlaid are the evaluations for TAs A, B, C, D shown in darker blue, purple, pink and green thinner bars respectively, and the TA averages in black.

Consider an observation among the instructors. Figure 2 shows a common trend in the perception of the faculty effectiveness and the class excellence. Faculty B and C were perceived more effective than faculty A. Their classes were perceived more excellent than faculty A's class. Faculty D was perceived more effective than faculty B, C and D. His/her class was perceived more excellent than the other three classes. Faculty B and C were perceived equally effective. Their classes were perceived equal. This trend is also true for TAs A, B, C, D.

Now consider an observation for each individual instructor. Figure 2 shows that the perception of the class excellence is either near or higher than the perception of the faculty effectiveness.

For example, faculty B, C and D's classes have evaluations near their effectiveness evaluations; faculty A's class has a 3.00 evaluation which is higher than his/her effectiveness evaluation at 2.50. The trend, however, is completely opposite for the TAs. The perception of the class excellence is lower than the perception of the TA effectiveness.

The classes taught by the TAs has the average of 3.94 for Teaching Alignment, 3.76 for Instructor Effectiveness, 3.42 for Knowledge Improvement and 3.2 for Course Excellence. The students concluded that the Ph.D. candidates are as equally effective instructors as the faculty. However, their classes were not as excellent as those taught by the faculty.

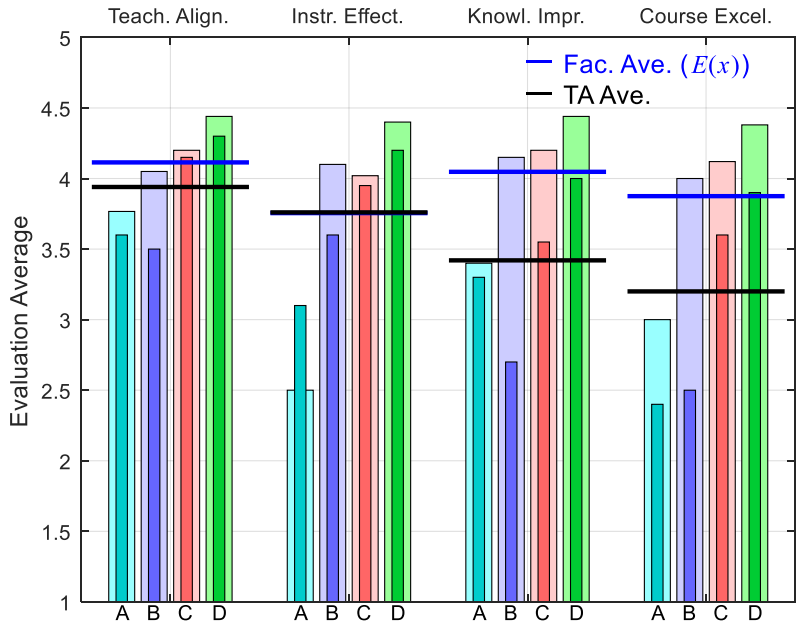

Figure 2. Performance of TAs in academic year 2018 – 2019

Conclusions

Capstone senior design classes have been taught by designated faculty for many years. Because each faculty is unique in his/her own way, a lack of consistency across classes is expected. Under the new practice, the classes were taught by Ph.D. candidates. Because the Ph.D. candidates were trained weekly by one selected faculty, consistency across classes could be achieved. However, the debate has been the trade-off in quality. This paper answered the question by looking at the evaluations in four important aspects of course: the alignment of the instructor's teaching with the course learning objectives/outcome, the effectiveness of the instructor, the improvement of the student's knowledge of the subject, and the excellence of the course. These evaluations are based on the perceptions and not on measured parameters.

The faculty evaluation averages as well as the departmental average from Fall 2015 to Spring 2018 were measured against the desirable evaluation. While meeting the desirable evaluation in teaching alignment and knowledge improvement, the department was bordering below desirable in instructor effectiveness and excellence of the course.

The evaluations for five Ph.D. candidate-instructed classes in the academic year 2018-2019 were analyzed. While the inconsistency across classes continue to exist, the Ph.D. candidate instructors were as equally effective as the faculty. Their classes were perceived as of lesser quality than those taught by the faculty.

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