Student Benefits of Multidisciplinary versus Single-Disciplinary Design Experiences: A Cohort Study of a Capstone Design Program

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STUDENT BENEFITS OF MULTIDISCIPLINARY VERSUS SINGLE-DISCIPLINARY DESIGN EXPERIENCES: A COHORT STUDY OF A CAPSTONE DESIGN PROGRAM

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Introduction

This work in progress describes a cohort study of a recent modification to a well-established capstone engineering design program [1,2] to incorporate multidisciplinary student teams. As such, it presents a unique opportunity to evaluate student outcomes as it relates to working within multidisciplinary versus single-disciplinary teams for substantive engineering design projects. There has been much emphasis placed on the benefits of multidisplinary instruction and teaming [3-5] with little evidence to support such claims, in part because opportunities to directly compare multidisciplinary versus single-disciplinary teaming experiences are relatively rare.

The capstone engineering course, Senior Design, historically has been a 6-credit, one semester course in fall semester for senior mechanical engineering undergraduates at a mid-sized, research-intensive university [1,2]. For the past three decades, Senior Design has involved teams of 4-5 students working on one of 15-25 projects sponsored by local industry, engineering firms, and in some instances industry-affiliated academic groups. A team of 4-6 full and part-time mechanical engineering faculty manages the course; each faculty member advises 3-5 teams each. Beginning in 2012, the newly formed biomedical engineering program adopted the mechanical engineering model for Senior Design and merged a large cohort of its students into interdisciplinary teams with mechanical engineers. More recently, smaller cohorts of electrical engineering and environmental engineering students have also joined the multidisciplinary section of the course, which focuses on projects in the biomedical, environmental, and industrial design sectors. Project sponsors represent the biotech and environmental engineering industries, the clinical sector, and non-profit and start-up entities.

The recent rollout of our multidisciplinary senior design program provides us with a unique opportunity to evaluate the effectiveness of this approach in relation to overall career readiness as well as select “soft skills” such as project management and ability to work in multidisciplinary teams. Presently, we have relatively large cohorts of recent graduates from both the single (<2012) and multidisciplinary (2012+) sections, and, in this study, they were assessed on their experiences in the senior design program. The findings from this work-in-progress study will provide empirical support for multidisciplinary experiences for students by highlighting educational and career-development benefits.

Methods

The impact of the multidisciplinary design program on the mechanical engineering undergraduate program was assessed as a subcategory of outcomes in our Department’s standard alumni survey, which is administered approximately every five years as part of the ABET accreditation process. In Fall 2015, an online survey was distributed to all alumni of the department with active email addresses (N=2301) via repeated emails (Constant Contact) with links to an online survey system (Qualtrics). Responses were solicited for a two-week period from mid-September to early October 2015.

The survey commenced with questions about our current curriculum and our alumni's satisfaction with their overall level of preparation for their respective careers. This was followed questions about self-perceptions and importance of three core areas of emphasis for our undergraduate program, namely, Active Learning, Professional Development, and New Technologies. Assessment items for the Senior Design experience were embedded in both the Active Learning and Professional Development sections (Table 1). Survey items were mapped to a 4-point Likert scale, with higher values corresponding to more positive outcomes. To assess the impact of interdisciplinarity of the Senior Design, the survey cohort was segmented by graduation year into prior to (<2012) and post (2012-2015) Multidisciplinary Senior Design. Pre versus Post Multidisciplianry comparisons were made using one-way ANOVA (JMP Pro v12).

Results

The survey response rate was 6.6%, with respondents representing a wide range of graduation years (range: 2015-1945), with concentrations in 2010-2015, 1992-1995, and 1980-1982. Only undergraduate alumni who completed the survey were included for further data analysis (N=132). There was a substantive and statistically significant improvement in the self-perceived effectiveness of the Senior Design Program following its conversion from single-disciplinary to multidisciplinary (Table 1, $p<0.01$, $d=0.61$). There were also substantive gains in select Professional Development skills, including "Working in Interdisciplinary Teams," "Project Management," and others (see Table 1).

Table 1: Results for survey questions related to Senior Design, specifically, the self-perceived effectiveness of the Senior Design program as well as key aspects of Professional Development. All results scored on 4-pt Likert Scale with 4=Excellent and 0=Poor. Results are presented for the entire survey population (All) as well as pre (<2012) and post (2012-2015) launch of the Multidisciplinary Senior Design Program. Pre vs. Post outcomes compared using ANOVA with $p<0.05$ for significance.

	All		**Pre (<2012)**		**Post (2012-2015)**		**Pre vs. Post ANOVA**	**Effect Size**
	Mean	**St.Dev**	**Mean**	**St.Dev**	**Mean**	**St.Dev**	**p-value**	**4-Pt Likert**
Effectiveness of Senior Design	3.32	0.97	3.17	1.05	3.78	0.42	<0.01	0.61
Project Management	1.63	1.17	1.41	1.08	2.28	1.21	<0.01	0.87
Business Decisions	1.09	0.97	1.03	0.93	1.28	1.10	0.26	
Working in Multidisciplinary Teams	1.71	1.35	1.41	1.20	2.60	1.38	<0.01	1.19
Supervising Others	1.07	1.06	0.86	0.92	1.68	1.22	<0.01	0.82
Being Supervised	1.55	1.10	1.36	1.05	2.12	1.09	<0.01	0.76
Dealing with Conflict	1.16	1.06	0.95	0.97	1.80	1.08	<0.01	0.85
Professional Networking	1.15	0.98	1.01	0.96	1.56	0.92	0.02	0.55

Discussion

The results of our work in progress study clearly suggest that the addition of multidisciplinarity to our established senior design program improved the overall effectiveness of the program along with development of select "soft" skills, most notably working in multidisciplinary teams, project management, and dealing with conflict. A strength of our study was that we strictly surveyed alumni, who naturally provide prospective on the value of the senior design experience as it relates to career preparation. However, because many of our alumni lacked a context for the multidisciplinary version of our program (alumni who graduate prior to 2012), we were unable to directly question our survey population about the issue of multidisciplinary teaming. Although this is a study limitation, it is mitigated by the fact that multidisciplinary teaming was the only major curricular change to the Senior Design program over the graduation years surveyed in our study. From a logistical and pedagogical perspective, there were few difficulties implementing multidisciplinary teaming in our Senior Design program, largely due to the fact that several of the faculty instructors taught underclassmen design-based courses in the two programs with the majority of participating students (mechanical and biomedical engineering). An effort was made, particularly in the junior year, to prepare students for teaming across disciplines by introducing cross-disciplinary concepts, e.g., computer aided design for biomedical engineers, and using a consistent 4-phase design process framework in all courses. To the best of our knowledge, ours is the first study of its kind to isolate the effects of multidisciplinarity on student outcomes in a capstone design course [3-5], and, as such, it may be used as evidence for wider adoption of this approach.

References

[1] Keefe, M., J. Glancey, and N. Cloud. "Assessing student team performance in industry sponsored design projects." *Journal of Mechanical Design* 129.7 (2007): 692-700.
[2] Keefe, M., J. Glancey, and N. Cloud. "A Case Study in Assessing Team-Based Design Courses That Integrate Industry-Sponsored Projects." *ASME 2005 International Mechanical Engineering Congress and Exposition*. American Society of Mechanical Engineers, 2005.
[3] Miller, Ronald L., and Barbara M. Olds. "A model curriculum for a capstone course in multidisciplinary engineering design." *Journal of Engineering Education* 83.4 (1994): 311-316.
[4] Todd, Robert H., et al. "A survey of capstone engineering courses in North America." *JOURNAL OF ENGINEERING EDUCATION-WASHINGTON-* 84 (1995): 165-174.
[5] De Vere, Ian, Gavin Melles, and Ajay Kapoor. "Product design engineering–a global education trend in multidisciplinary training for creative product design." *European Journal of Engineering Education* 35.1 (2010): 33-43.