The Effects of Interdisciplinary Collaboration in Completing a Radiological Engineering Design Project

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Introduction

An important skill for engineers to obtain is the ability to perform on cross-disciplinary teams. In fact, the accrediting organization ABET has deemed this a key student outcome for nuclear engineering programs.[1] The nuclear engineering program at the United States Military Academy (West Point) offers a unique perspective on the ability of students to perform on cross-disciplinary teams because non-engineering majors are required to take a 3-course core engineering sequence (CES); hence, non-engineering students take ABET accredited engineering classes along with engineering majors. The West Point course NE350, Radiological Engineering Design, provides students with a design project that is completed by (in most cases) 3-person teams. These teams are composed of a mix of nuclear engineering students, physics students, and humanities students from across the academy.

The term cross-disciplinary is used to describe both multi-disciplinary and interdisciplinary. The Committee on Facilitating Interdisciplinary Research explained that a multidisciplinary team comes together to accomplish a project with each member of the team contributing according to his or her unique expertise and then separates when the task is accomplished, whereas an interdisciplinary team works in a more integrated manner combining their knowledge toward a solution.[2] Generally speaking, engineers tend to lean toward the multidisciplinary approach when collaborating on a project.[3] Nevertheless, it has been shown that engineering education faculty researchers who collaborate in a truly interdisciplinary approach tend to have better quality of work and increased satisfaction.[4] While this may be true amongst faculty researchers, there is little evidence of the impact of interdisciplinary collaboration amongst students.[5] The purpose of this article is to gain insight into how well student teams at West Point approached the ideal model of an interdisciplinary collaboration and show its effect on the quality of work and level of learning while completing a radiological engineering design project that had both engineering and social science aspects.

Method

NE350 students completed a radiological engineering design project on either a cross-disciplinary team or an engineer-only team. 47 students in 3 different sections completed the project. There were 17 teams: 13 three-person groups, and 4 two-person groups. Student majors included Nuclear Engineering (18), Physics (7), Economics (6), International History (3), International and Comparative Legal Studies (2), Chemistry (2), Chinese (1), Spanish (1), Russian (1), Arabic (1), International Relations (1), Psychology (1), Kinesiology (1), American Politics (1), and Mathematical Sciences (1). Students were allowed to select their own teams by passing around a sign-up sheet with slots for each of the 17 teams.

The project itself consisted of teams designing a hasty radiation-shielded transportation container for a potential radioactive dispersion device in a fictional military situation using a limited supply of materials. Graded items included 3 In-Progress Reviews (IPRs), a laboratory, and a final written report of their design.

The purpose of the first IPR was to recognize the problem; develop a problem statement; determine specified, implied, and essential tasks; research previous work in the field; develop requests for information; determine any restrictions, limitations, and/or constraints; develop a research topic list and organize the project using project management tools and techniques. All of these tasks were to be performed with consideration given to the economic, social, political, ethical, technical, health, and safety aspects of the project environment.

In the Second IPR students developed a few courses of action (COAs) and used a specific procedure, modeled after the military decision making process (MDMP), to evaluate the COAs and select the best one. Students performed some preliminary calculations to help determine the feasibility of their COAs.

For the third IPR, students provided their design description and specifications and performed all the necessary calculations and risk assessments to ensure their design met the maximum allowable radiation dose limit and satisfied their problem statement and essential tasks.

The final written report was a standalone document that included the final design descriptions and specifications. It included discussions on their approach, assumptions, results, conclusions, and recommendations.

The laboratory was an opportunity for cadets to gain experience using detection equipment and to determine the radiation protection properties of their specific shielding materials.

The course content included topics that supported the design project to include radiation shielding, radiation detectors, nonproliferation, the design process, probabilistic risk assessment, and others.

It was expected that the math, science, and engineering (MSE) majors in the class would excel with the technical piece of the project and that the other students would broaden their perspective and provide expertise on the social, economic, ethical, and political aspects of the project.

In order to determine the effects of the design team composition and see if the cross-disciplinary teams had any synergistic advantage, a voluntary, anonymous survey was administered at the end of the semester after the final written report was submitted. Questions were designed to determine the makeup of the groups (engineers, science/math, or “other” students). They were then asked the following questions:

1. To what extent are you satisfied with your team's design project?
    a. very satisfied
    b. somewhat satisfied
    c. neither satisfied nor dissatisfied
    d. somewhat dissatisfied
    e. very dissatisfied

2. To what extent did you learn something as a result of this project?
    a. I learned very much
    b. I learned somewhat
    c. I learned very little
    d. I did not learn anything

3. Did having someone on your team who was not in your major group (Engineering, Math/Science, Other) help you to see things from a different perspective?
    a. Yes
    b. No
    c. N/A

4. Indicate your methodology in completing tasks in the design project:
    a. We completed tasks separately. We divided the tasks according to each individual's area of expertise.
    b. We completed tasks separately. We divided the tasks, but we did not consider anyone's particular area of expertise.
    c. We worked together in an integrated approach to complete the project
    d. Only one person did all the work.
    e. Other. Please explain.

5. In completing your design project, was your opinion valued as much as the other team members?
    a. Yes
    b. No

Results

38 of the 47 students in the course completed the survey. The data was analyzed and respondents were placed into one of 8 categories based on the composition of their team: engineer only; engineer and math/science; math/science only; engineer and "other"; engineer, math/science, and "other"; math/science and "other"; and "other" only. The respondent team breakdown is found in table 1 below.

Table 1: Breakdown of the type of team to which survey respondents belonged

Respondent Team Type	#	Percent of Total
Engineer Only	11	29%
Engineer and Math/Science	0	0%
Math/Science Only	3	8%
Engineer and "Other"	8	21%
Engineer, Math/Science, and "Other"	1	3%
Math/Science and "Other"	9	24%
"Other" only	6	16%
Total	38	100%

Because of the small sample size of each of the groups and the small variation in the survey results between the engineering and math/science majors, it was decided to lump the respondents into one of 3 categories: MSE only teams, Cross-disciplinary teams, and Non-MSE only teams. The breakdown of the respondents in these categories is given in table 2.

Table 2: Generalized breakdown of the type of team to which survey respondents belonged

Respondent Team Type	Respondents	Percent of Total
MSE only	14	37%
Multidisciplinary	18	47%
Non-MSE only	6	16%
Total	38	100%

The results to question 1 regarding project satisfaction are shown in figure 1. The responses were given a numerical value from 1 to 5, 1 being very dissatisfied and 5 being very satisfied. The mean response among MSE majors was 4.36 with a standard deviation of 0.81. The mean response among cross disciplinary students was 3.50 with a standard deviation of 1.21. The mean response among Non-MSE only students was 2.83 with a standard deviation of 1.07.

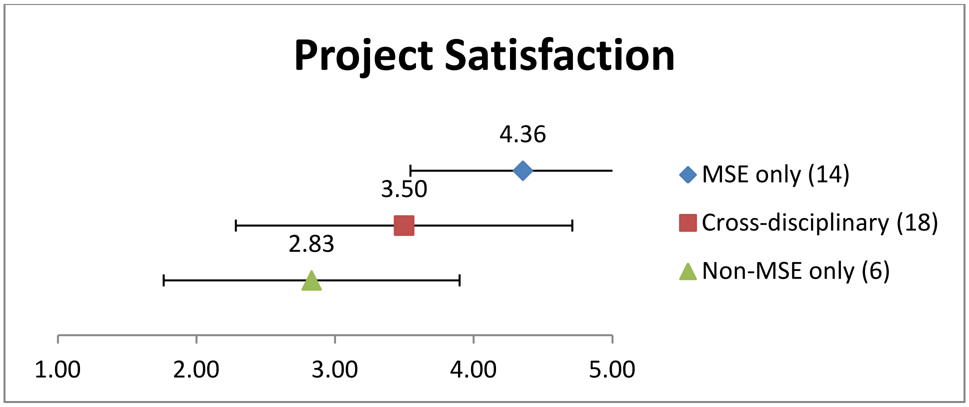

Figure 1: Breakdown of survey respondents' results to the question, "To what extent are you satisfied with your team's design project?" 1=very dissatisfied, 2=somewhat dissatisfied, 3= neutral, 4=somewhat satisfied, 5=very satisfied.

There was a clear trend toward greater project satisfaction as the teams increased the percentage of MSE-discipline students. Nevertheless, the standard deviation in each of these categories is sufficiently large to cast doubt on the results.

Likewise, the level of learning question shows a similar trend (See figure 2). The responses were given a score from 1 to 4, 1 being "I did not learn anything," and 4 being "I learned very much." The MSE-only team members averaged 3.29 with a 0.70 standard deviation. The cross-disciplinary team members averaged 2.89 with a 0.66 standard deviation. The Non-MSE only team members reported an average of 2.33 with a 0.94 standard deviation. Once again, the sample size was too small to report a strong level of confidence in these results but there was a clear trend that the greater the percentage of MSE students on a team, the greater the level of learning reported by the individual team members.

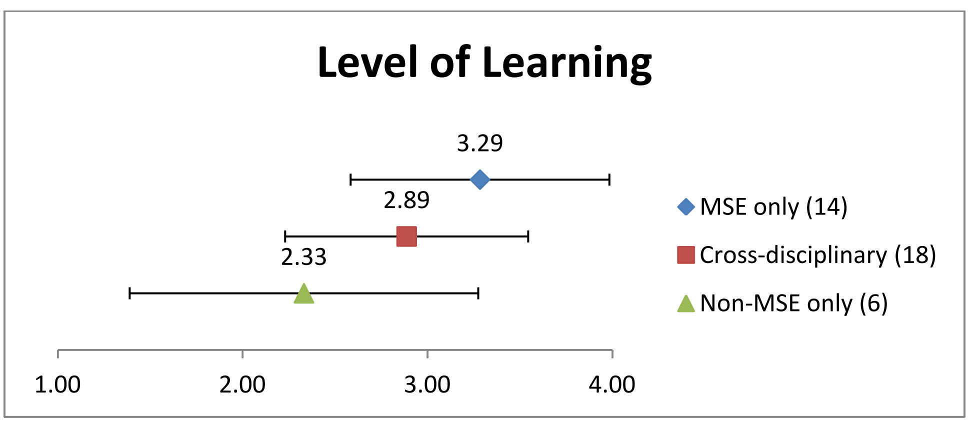

Figure 2: Breakdown of survey respondents' results to the question, "To what extent did you learn something as a result of this project?" 1=I did not learn anything, 2=I learned very little, 3=I learned somewhat, 4=I learned very much.

The quality of work from each of the 17 design teams, as reflected in their assigned grades, is given in figure 3. Once again, the results show that the quality of work improved as a function of the percentage of engineers on the team.

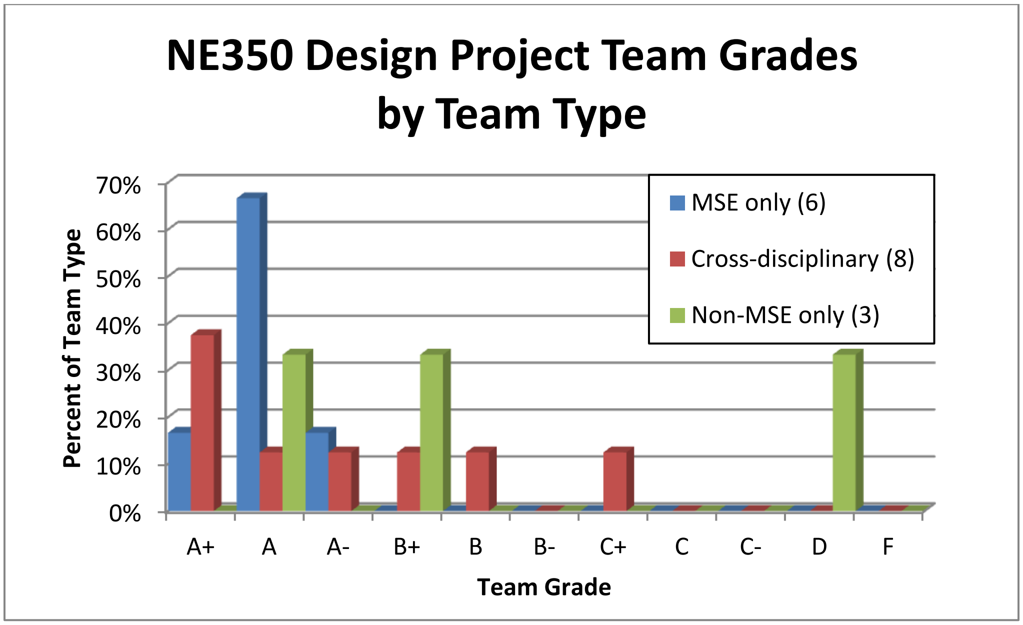

Figure 3: Breakdown of team grades as assigned by their instructor for the NE350 design project.

Aside from these results showing a tendency for the engineer heavy teams to perform better than their classmates, it was also important to determine if how closely a cross-disciplinary team approached the interdisciplinary model had an effect on the project satisfaction, level of learning, and quality of work. Figures 4 and 5 depict the reported satisfaction level and level of learning, respectively, between the two types of cross-disciplinary teams – multidisciplinary and interdisciplinary – based off their response to question 4. With the small sample size, no statistically significant correlation between the method of project completion and satisfaction or learning level emerges.

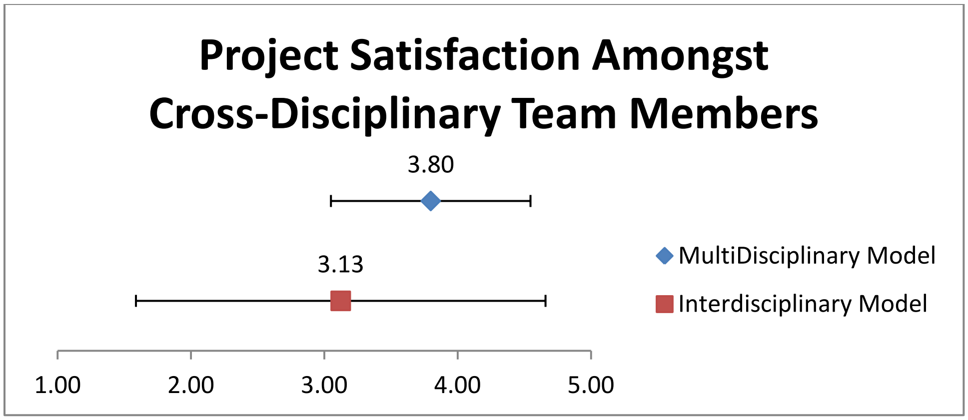

Figure 4: Breakdown of reported project satisfaction amongst only the cross-disciplinary team members. Multidisciplinary indicates that they completed the project by dividing the tasks and completing them separately, as opposed to working together in an integrated approach (interdisciplinary). 1=very dissatisfied, 2=somewhat dissatisfied, 3= neutral, 4=somewhat satisfied, 5=very satisfied.

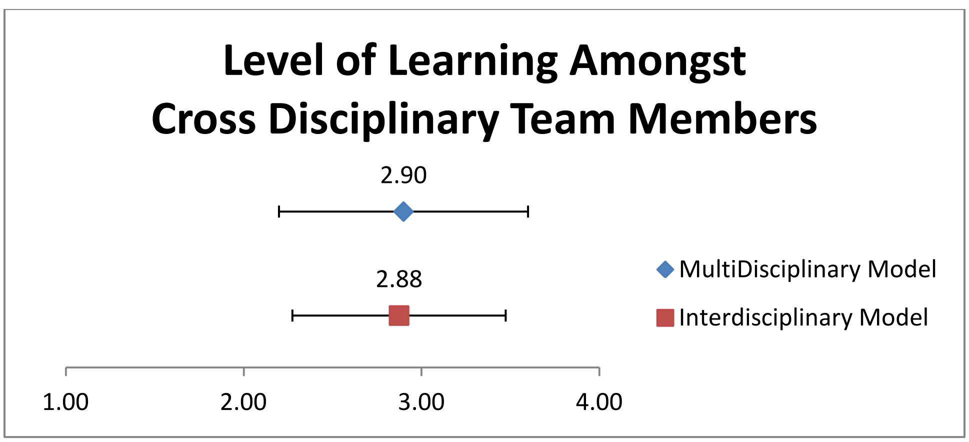

Figure 5: Breakdown of the reported level of learning amongst only the cross-disciplinary team members. 1=I did not learn anything, 2=I learned very little, 3=I learned somewhat, 4=I learned very much.

Discussion and Conclusion

When this study was conceived there was an expectation that cross-disciplinary students who worked closely together in an integrated approach would outperform their counterparts who had a homogeneous blend of students. This study shows that, in fact, the homogeneous blend of MSE students outperformed both the non-MSE students and the cross-disciplinary teams. While there is some doubt cast in the results due to the small sample size, there appears to be a nearly linear relationship between the percentage of MSE students on the design teams and the level of learning and project satisfaction. Even the grades received for the project follow this pattern.

One explanation for these results could be that the engineers in this population chose their major and therefore were more interested in the topic and were more willing to put forth a greater effort than those students who were merely taking the course as part of their required core engineering sequence (CES). It has been shown that collaborations are more effective when all parties involved are deeply interested in the project.[3]

Another possible reason for the disparity between MSE and non-MSE students is that the non-MSE discipline students were intimidated by the technical aspect of the project and felt that their input was not valuable. This possibility, however, is refuted by analyzing the responses to question 5 that asked if their opinion was valued as much as the other members of their team. Every single non-MSE respondent indicated that their opinion was valued as much as their teammates.

While non-MSE students do have much value to add to design teams in completing an engineering project, in order to gain any benefit they must be deeply interested in the project. The student's attitude toward the subject matter appears to be the most important factor in determining the level of learning and project satisfaction. Non-MSE students should be open to learning something new and encouraged to contribute their expertise, especially when considering the political, social, economic, ethical, and health and safety aspects of the project.

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