

Work in Progress: Impact of individualized personal development projects in a Multidisciplinary Capstone course on project success and student outcomes

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Work in Progress: Impact of individualized personal development projects in a Multidisciplinary Capstone course on project success and student outcomes

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Introduction:

The Capstone Design course is a culminating course in many engineering curricula, specifically fulfilling the ABET 5.d criterion of “a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.” (ABET, 2023) At Penn State, the one-semester Multidisciplinary Capstone course has been designed to facilitate team formation with students from across multiple engineering departments, providing an analogue to the real-world engineering teams on which the students will find themselves in their careers. Each engineering department hosts sections of the course, with projects assigned to the courses and their instructional faculty. The projects are sourced from industry or from University research laboratories, with the faculty and the sponsors refining the project, pre-semester, to best elucidate the needs of the project from a student educational-background perspective.

Students are assigned to capstone projects through a semi-automated system that takes into account their project preferences, as well as their major, and the project needs. Shortly, students navigate to a webpage that has the semester’s available projects in a database. Students can only see projects that have identified their major as necessary for project success. Students then provide preferences of projects that interest them or for which they feel their skillset is well-suited; up to 10 may be selected. They may also identify up to 5 projects for which they feel they are not a good fit or do not have the necessary skillset. An automated algorithm then places students onto initial project teams. Section instructors evaluate the students that have been assigned to their projects and determine if the project needs are well met. If they are not, they are able to contact other instructors to trade students amongst projects.

My observations during several semesters as a Capstone instructor are that it is not uncommon to have students that are not well-matched to their projects, or projects for which the necessary student background was not met. This results in a variety of negative outcomes including: 1) poor project results; 2) poor student experiences; 3) poor intra-team communication; 4) siloing of project work responsibilities (e.g. “you know how to do that, so you take care of it”). These observations are supported by previous published literature (Paretti 2011; Mosher 2014, Mostafapour 2020). The observed mismatch is not a consequence of the semi-automated team assignment system, which undergoes continuous improvement, but rather due to the unpredictability of the number of projects each semester, the specific needs of those projects, the number of students from each major taking Capstone that particular semester, and those students preferences regarding the available projects.

Potential systemic solutions to these issues all have clear limitations. Removing the ability of the students to provide project preferences would likely exacerbate the enumerated problems. Requesting that sponsors provide a larger number of potential projects that could be implemented selectively depending on the distribution of student majors in a given semester is an excessive burden on sponsors and likely would not reflect their needs regarding potential immediacy of solutions.

In this work-in-progress paper, I describe a possible instructor-student level solution to these observed issues. The methods by which the solution was developed and those to evaluate the efficacy are described, followed by the observed results and discussion, and finally some concluding remarks and future plans for this potential solution.

Methods:

As part of Penn State College of Engineering Leonhard Center-led Entrepreneurial Mindset for Innovative Teaching (EMIT) Academy, I developed a potential solution to the issue and piloted it in my Fall 2022 Multidisciplinary Capstone course. Idea generation for the project/skill mismatch issue were developed resulting in two promising potential solutions: 1) assigning students a personal development project early in the semester to support project needs; and 2) working with sponsors to implement adjacent or “stretch” goals that may better align with student skillsets. Stakeholder feedback was requested to determine the experiences and opinions of former students, former project sponsors, and fellow instructors to these possible solutions. Five previous students, one previous sponsor, and one fellow instructor were reached. A survey was provided to students through Microsoft Office Forms, a questionnaire was provided to the sponsor via email, and a Zoom call was arranged with the fellow instructor. I acknowledge that this is a limited set of stakeholders which may bias the findings, which I propose to improve in the future by querying prospective students and sponsors, as well.

The students were asked a series of questions with responses on a 5-point Likert scale, with additional options to provide open-ended comments. The questions were created and revised in coordination with other participants of the EMIT Academy. The first set of questions was regarding their previous Capstone experience with the questions listed in Table A1 of the Appendix, with the scale from “Not at all” to “A lot”. The goal of these questions was to elicit responses about how well they thought their team make-up reflected the project needs.

Next was a series of questions to gauge their viewpoint on requiring a personal skill development assignment, rated from “Much worse” to “A major improvement”. The goal of these questions was to elicit how they believe such an additional assignment would have affected their experience with the course, their interactions with their teammates, as well as their sponsor. These questions are shown in Table A2 of the Appendix.

Finally, a series of questions to evaluate their viewpoint on the sponsors creating adjacent or “stretch” goals to better fit the teams skillset, rated from “Much worse” to “Greatly improved”. These questions are shown in Table A3 in the Appendix. In the same manner as the personal assignment, the goal was to elicit how they felt it would affect their course experience, interactions with teammates and sponsors.

The sponsor and the fellow instructor were given a description of the two possible solutions and asked directly what their viewpoints would be on such changes, without a Likert scale. The goal of these questions was to determine how either a personal development assignment or adjacent/stretch goals would affect the sponsor/instructor experience with their Capstone teams.

After the results of the stakeholder input (described in the next section), I decided to move forward with the personal skill development assignment for each student. This was implemented after the student teams had met with one another and their sponsor during the first week of class to discuss their backgrounds and the needs of the project. Each student was asked to reflect on their own skillset and the needs of the project and asked to propose a skill that they would like to develop, one which they did not already have, which would likely have relevance to the project outcomes. Further, they were asked to propose a course of action by which they would develop this skill. This could include online tutorials, in-person training, peer-to-peer mentoring, or whatever else the students might identify. This assignment was due at the end of

the second week of class. I evaluated each response and then met with the students individually to either approve their course of action, help them refine it, or ask them to re-evaluate.

Throughout the rest of the semester the students were expected to pursue their course of action and apply their new skills to the project, as needed. During the semester, I evaluated their progress in an ad-hoc manner through observations during weekly meetings with each team to discuss progress on their project. At the end of the semester, the students took a survey to gather feedback regarding the personal skill development assignment. This was a graded assignment to maximize the response rate. The grading philosophy was regarding the completeness and level of self-reflection that the student provided rather than desired responses. This was made clear to the students prior to assigning the survey. The survey consisted of eight questions and then options for open-ended comments. Questions requesting ratings were on a 7-point Likert scale. The eight questions are shown in Table A4 in the Appendix. These questions were designed to elicit information on the student’s confidence levels with their selected skills, their previous background, their designed approach to developing the skill, the impact of the skill development on the student’s involvement in the project, and their comfort level with learning new skills.

Results and Discussion:

Figure 1 shows the survey results from the initial survey of past Capstone students requesting information on their experience. Overall the results show a broad range of responses from a poor experience to an excellent experience. This matches my knowledge of the students that I was able to survey. Teams that performed well in their project appeared to have a good distribution of student skillsets and viewed their workloads as well divided. Teams that performed less well and/or demonstrated frustration to me during the semester reflected that in their survey results.



Figure 1: Results from Stakeholder Input Surveys from Table 2: During Capstone please rate your project experience (n = 5)

Figure 2 shows the results from the question regarding the concept of a personal skill development assignment. Broadly, students thought this would be beneficial to them personally and for their project. One student viewed this very negatively, with open-ended comments stressing concerns about the additional workload.

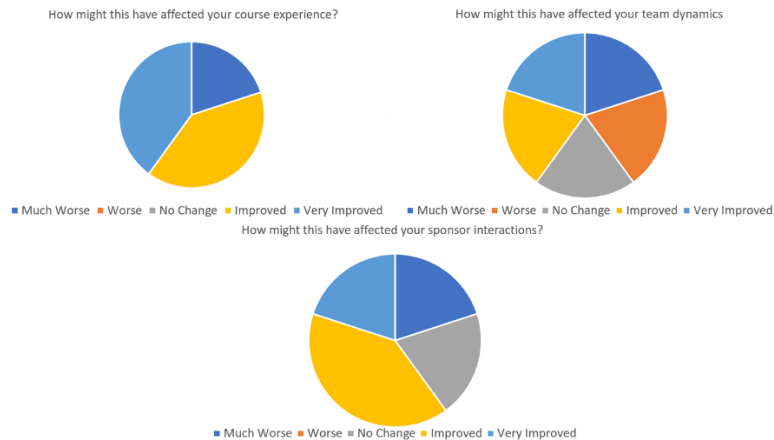


Figure 2: Results from Stakeholder Input Surveys from Table 2 regarding the effect of a personal skill development assignment (n = 5)

Figure 3 shows the results of the survey regarding the concept of the sponsor being more flexible with adjacent or stretch goals to match the student backgrounds. Perhaps not surprisingly, respondents broadly viewed this positively, most likely because it limited the need for the students to do more during the course.

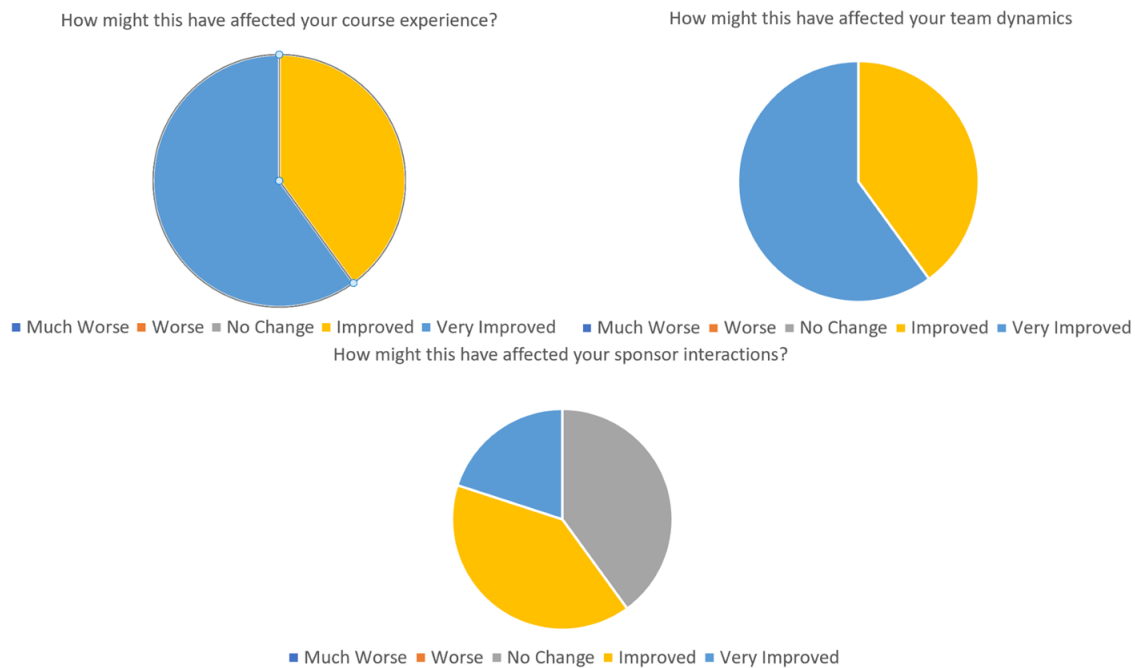


Figure 3: Results from Stakeholder Input Surveys from Table 3 regarding the effect of a sponsor being flexible to adjacent or stretch goals (n = 5)

The feedback from the sponsor, however, was much less enthusiastic about adjacent or “stretch” goals due to their past experience. The sponsor’s feedback was that the students often needed more focus and effort on the core goals of the project, and that they often had to reduce the project requirements. For this reason, as well, the sponsor was somewhat ambivalent to the personal development assignment. The instructor, however, was very enthusiastic about the personal skill development assignment, having experienced some of the same behaviors and events as I had. Collectively, giving greater weight to the sponsor’s remarks since they fund and provide the projects, I decided to move forward with the personal skill development project.

Fall 2022 Multidisciplinary Capstone course had four projects and 14 students. The distribution of student skillsets was not a great fit for three of the projects, providing an attractive initial testing environment for this assignment. Examples of personal skills to enhance project success included physical manufacturing/machining, Arduino/microcontrollers, computational fluid dynamics, computer-aided design (CAD) and additive manufacturing. Some of these were identified by multiple students. Examples of approaches to the skill development included one-on-one training in our engineering machine shop, workshops on Arduino and microcontrollers provided at our campus library, online tutorials from various sources including LinkedIn and Youtube, and some peer-to-peer learning.

Instructor observations throughout the semester were that approximately half of the students were expressing pride and excitement that they were learning new skills and applying them to their projects in unexpected ways. There was a smaller percentage of students that did not engage with the personal skill development assignment as hoped and one student for which their project goals changed, leaving their skill not helpful to the project. In general, for this small sample size, improvement, defined as increased engagement in the project through their skill development, was observed as a consequence of this assignment.

Figure 4 shows results for the post-semester survey regarding student confidence in their identified skill (top) and the perceived effects of the assignment on the project (bottom). These results show that prior to the semester, the students were generally unfamiliar with whatever technical skill they selected (>70% below average). This is not unexpected, since it was part of the assignment prompt. After the conclusion of the course, students self-reported much higher confidence (>75% above average) levels. This is a promising initial result in a small sample size. Regarding improving student involvement in their project, greater than 70% of students self-reported a greater level of involvement than expected based on learning the new skill. A slightly lower percentage, but still a majority (>60%) found their skill to be more than average importance to the success of the team’s project.

Figure 5 shows the results for the post-semester survey regarding the comfort level of students in learning new skills after this assignment. Greater than 75% of self-reported responses indicated a positive improvement in learning new skills after this assignment. Open-ended comments further reflect these results with some students indicating that they were previously “intimidated” or similar on learning new skills, but this experience made them more comfortable.

The primary limitations of these findings are the small sample size ($n = 14$, and 4 project teams), the graded nature of the final survey, which could bias student responses, as well as 2 – 3 students that either misunderstood the assignment or did not approach it in a serious manner. The latter I identified based on the response to open-ended questions and my in-class

observations. I plan to address the first two limitations by recruiting additional sections of the Capstone course to also use this approach, which will increase the number of students, allowing an ungraded survey which can tolerate a reasonable number of non-responses. The third limitation I plan to address by introducing official “milepost” meetings with each student at different points during the semester instead of the ad-hoc approach that I used. This will increase student accountability, as well as provide me with a more individualized insight into each student’s progress.

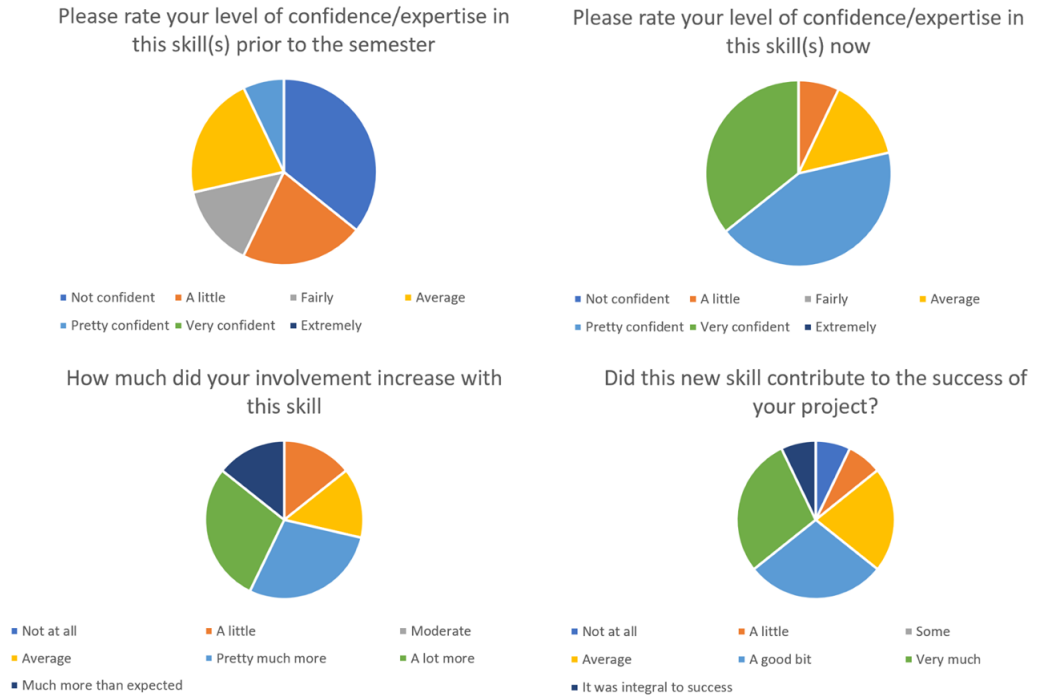


Figure 4: Survey results from after the semester, evaluating student confidence in their desired skill (top) and how this skill development affected the project (bottom) (n = 14)



Figure 5: Post-semester survey results regarding student self-reported comfort in learning new skills (left) and confidence if faced with unsupported skill learning at a new job (right) (n = 14)

Conclusions and Future Work:

This paper describes an approach to address the issue of poor student technical-background alignment with industry- or faculty-sponsored Capstone design projects. This misalignment can result in poor project outcomes, student experiences, intra-team

communication, and siloing of project responsibilities. A personal skill development assignment was developed to address this, based on student, sponsor, and instructor interviews. The personal assignment is developed by the student and instructor at the beginning of the semester and the student undertakes a self-guided approach to the skill development. This assignment was piloted in one section of Multidisciplinary Capstone at Penn State in Fall 2022, consisting of 14 students on 4 project teams. Self-reported outcomes by students indicate significant improvement in selected skill proficiency, increased engagement with their projects, and increased confidence in the ability to develop new skills. Limitations of the approach include the small sample size and insufficient individual student check-ins during the semester. Future plans include introducing official milestone meetings between student and instructor and engaging other instructors to pilot the approach in their own sections.

Citations:

ABET, “Criteria for Accrediting Engineering Programs, 2022 – 2023,” retrieved from <https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/#GC5>, 13 March 2023.

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Appendix:

Table A1: During Capstone please rate your project experience

| |
|---|
| How well did your skills/background/interests match your project? |
| How well did your team distribution (different backgrounds) match the project? |
| Did you find that your teammates were all able to contribute significantly to the project? |
| Were you able to learn new skills associated with your project or the course? |
| Did you feel like the sponsor was/would be responsive to new approaches that integrated from your background/interests? |

Table A2: Consider: if I had included a "personal" project to learn a new skill or significantly develop one associated with either the project or the course at large, in addition to the completion of the project. This would be decided upon during the first two weeks of class amongst your team, your sponsor, and input from myself. An example might be someone with a coding background making the additional effort to learn manufacturing or vice versa. You would have been required to periodically report on your progress and provide a short final written description:

| |
|---|
| How might this have affected your course experience? |
| How do you think this might have affected your team dynamics and project success? |
| How do you think this requirement might have affected the interactions with your sponsor? |

Table 3: Consider: your sponsor supported the pursuit of stretch or adjacent developments, proposed by the student team related to their background/interests, in addition to the core goals of the project. This would particularly be for students that perhaps weren't great matches for the project. An example might be if a student with machine learning

background pursued some machine learning analysis of a sponsor's project to improve/inform design changes. This was not something that the sponsor considered, but could be useful.

| |
|---|
| How might this have affected your course experience? |
| How might this have affected your team dynamics? |
| How might this have affected your sponsor interactions? |

Table 4: Personal skill development assignment survey questions from Fall 2022 Multidisciplinary Capstone Course

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|--|
| Please rate your level of confidence/expertise in this skill(s) prior to the semester |
| Please describe in 2 – 3 sentences your background, knowledge, awareness, or understanding of this skill/ability/tool prior to the semester |
| Describe the process by which you learned this new skill(s). If you used tutorials or workshops please explain these. If your goals for the personal project evolved over the course of the semester, please describe how. Minimum of four sentences |
| Please rate your level of confidence/expertise in this skill(s) now |
| When considering about how you thought you would be involved in your project at the beginning of the semester, how did learning this new skill impact your level of involvement in the project? Particularly in aspects of the project which you originally would not have expected to be involved |
| Did this new skill contribute to the success of your project? |
| To what degree did this personal development project impact your comfort level in learning new skills? |
| If you were asked at a new job to dive into an existing project and learn a new skill with limited/no support from another person, rate your level of confidence in doing this. |