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Reflective Exercises to Bridge the Gap in a Two-Term Industrial Engineering Capstone Sequence

Hugh L. McManus and B. Kris Jaeger-Helton
Northeastern University

Reflective team exercises are used on the last day of Capstone 1, and the first day of Capstone 2, to focus students on the challenges ahead, bridge the gap between the semesters, and get students off to a quick and directed start in Capstone 2. The last day exercise is a simple reflection focused on the upcoming "Day 1" of Capstone 2. The first day exercise uses a Strength – Weakness – Opportunity – Threat analysis to align the student teams and focus them on the new term. The exercises are described. Outcomes from 30 teams over two years are examined. The results provide insight into what the students worry about, how they perceive their teams' strengths and weaknesses, and how the students spend the time between terms. Some correlations between the exercise results and ultimate team performance are found.

Keywords: Reflective exercise, two-term sequence, teamwork, success factors

Corresponding Author: Hugh L. McManus, h.mcmanus@Northeastern.edu

Introduction

The undergraduate program in the Mechanical and Industrial Engineering (MIE) Department at Northeastern University requires a 2-semester capstone sequence. The Industrial Engineering (IE) division offers Capstone 1 in the Summer 1 and Fall terms. In Capstone 1, students are matched with faculty advisors and capstone problems, define their solution approaches, and do necessary background research and other preliminary and planning work. The bulk of the deliverable work is done in Capstone 2. Students from both Summer 1 and Fall terms take Capstone 2 the following spring.

The gap between the semesters can lead to a loss of momentum for some project teams. This is particularly problematic for the students who take Capstone 1 in the Summer 1 term, as they have a 6-month gap. No work is required during this time, and students are often on co-op or otherwise away from campus. The students who take Capstone 1 in the Fall have only the usual winter break between terms.

In an effort to frame the break in a constructive way, a pair of exercises are done on the last day of Capstone 1, and the first day of Capstone 2. These exercises serve several purposes. They allow the students a period of reflection to consolidate the learning from Capstone 1 and think about the challenges of Capstone 2. They focus the teams on their goals for Capstone 2 and the most urgent problems they need to address to succeed. Finally, they provide an opportunity for team bonding through brainstorming and collaborative thinking. The exercises and some interesting results are presented here.

Background

These exercises are part of a new capstone program for the IE division. The previous program, which was unified with the Mechanical Engineering (ME) division, had disadvantages for IE students, including non-targeted class content, student dissatisfaction, and a performance gap between the IE and ME students.[1] The new program contributes to all categories of the ABET assessment standards, and satisfies a university requirement for Writing-Intensive Courses.[2] It is a testbed for innovations such as Readiness Reviews,[3] outside Design Reviews, Three Intelligences methods[4] and others.

The exercise described here uses reflection to help the students consolidate their knowledge, assess the state of their project, and gauge their own readiness to proceed. The concept of learning through reflection is well studied and will not be reviewed in depth here. Reflection in the capstone environment is nicely explained by Shay et al.[5] They note that it allows "students to pursue deeper, more creative solutions to problems, to form more cohesive teams, to be more deliberate in their decision-making and to avoid the last-minute rush to completion" that can typify capstone projects.

The exercise on the first day of Capstone 2 uses a Strength – Weakness – Opportunity – Threat (SWOT) analysis. This is a traditional method used in business, systems engineering and process improvement contexts. Its origins go back at least to the 1960s.[6] It is in widespread if somewhat scattered use in capstone classes and projects, particularly in business and healthcare settings.

Last Day Reflection

On the last day of Capstone 1, student teams are asked to reflect on and respond to three simple prompts. Based on the first one, this is referred to as the "Day 1" exercise. The allusion to the Amazon slogan "It's always Day 1" is intended, and briefly discussed.[7] The prompts are:

- It's Day 1 of Capstone 2!
  What are you going to do?
- What will prevent a successful day one?
- What will motivate you to succeed?

The prompts are introduced one at a time with 10+ minutes of work time after each. Students are instructed to discuss the questions in teams and note their answers on a simple worksheet. After all the questions are answered, the teams briefly present their work to the class. Finally, the teams are given the opportunity to update their answers based on what they learned from the other teams. They give 1-3 short answers for each of the prompts.

Results: Last Day of Capstone 1

The results of the exercises were collected from 30 teams of 4-5 students (a total of 133 students) over the course of Capstone 1 classes in Summer 1 2022, Fall 2022, Summer 1 2023 and Fall 2023. No differences in the level of effort, interest, or types of answers were noted between the different classes.

The results were compiled by coding for categories of activities. The activities anticipated by groups for Day 1 of Capstone 2 are shown in Figure 1. Project work encompassed technical activities specific to the project, identified by words such as test, prototype, and code. Planning activities included planning, scheduling, meeting etc. Reflection included sharing, compiling, and synthesizing information. The other categories are straightforward; IRB refers to the Institutional Review Board, which approves human subject experiments. More on that later.

The barriers mentioned were fewer in number and more diverse than the plans. The largest categories are shown in Figure 2. The teams often mentioned countermeasures along with the barriers. The most common mentioned were increasing communication and planning (13 responses), obtaining further knowledge (6), down-scoping and asking for help from the advisor (4 each) and straight-up doing more work (4).

The answers to the final question were too varied to categorize here. Students expressed excitement at the opportunity to create or apply new technologies, help streamline operations at hospitals and non-profits, and create new virtual laboratories and simulations. They were happy to create social goods, and also to learn career-enhancing technologies and perhaps create patents or academic papers for their own resumes.

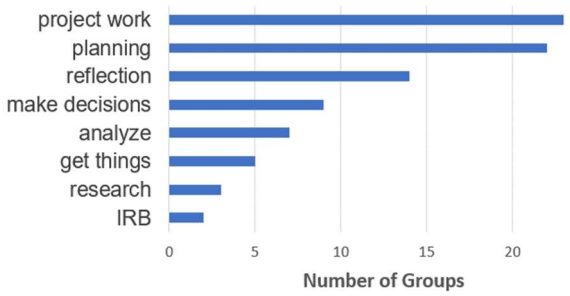

Figure 1. Planned activities on Day 1 of Capstone 2

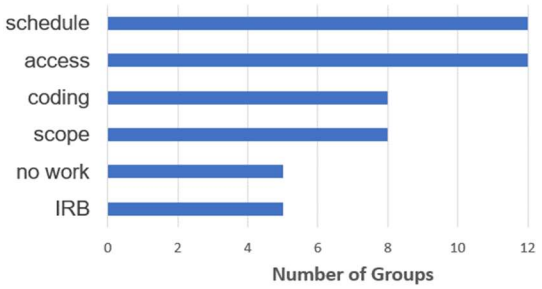

Figure 2. Barriers to success on Day 1

First Day SWOT exercise

On the first day of Capstone 2, students were given some time to mingle and re-introduce themselves after what for some of them had been a long break. The Spring Capstone 2 class included teams from both the Fall Capstone 1 class (who had been away only for a winter break) and the Summer 1 Capstone 1 class (who had been gone for over 6 months).

The teams were given a simple 3-question assessment:

- How's it going?
- Get work done since Capstone 1?
- Ready to go now?

The questions were answered on a Likert "smiley" scale to make it easy and quick (and perhaps a bit fun).

The teams were given their answers from the "Day 1" exercise from the end of Capstone 1 and asked to reflect on their answers. They were then given a SWOT worksheet (Figure 3) to brainstorm the Strengths and Weaknesses of their team and assess the Opportunities and Threats that faced them in their final term.

Figure 3. SWOT Template

Finally, they were asked to do the exercise often described as TOWS, although the students preferred the moniker LARD after the words identifying the quadrants in Figure 4. The idea was to brainstorm how Opportunities matched with Strengths could lead to Awesome results, Threats parried with Strength could lead to Resilience, Opportunities matched with Weakness could lead to missed opportunities (although maybe also lucky breaks), and Threats countered Weakly could lead to Disaster.

Figure 4. TOWS (or LARD) Template

Results: First Day of Capstone 2

The results of the "smiley" exercise are shown in Figures 5 and 6. A stark difference between the teams from Summer 1 and Fall was evident. The summer teams (with the long break before Capstone 2) were less satisfied with their work over the break, but *more* confident that they were ready to start Capstone 2. Both differences were statistically significant (at $p = 0.07$ and 0.03 respectively, digitizing the smileys). Even more interestingly, Figure 6 shows that the "got work done" distributions were very different, with the Summer 1 results being bi-modal – some teams worked, some did not. The higher smiley value of the Fall students probably has to do with reduced expectations over the

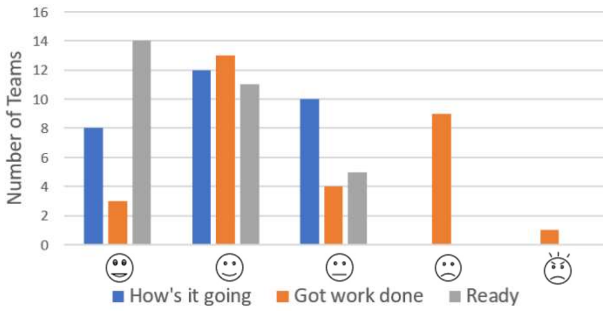

Figure 5. Smiley Survey (all teams)

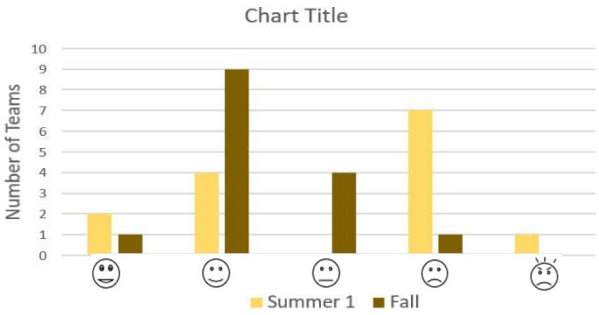

Figure 6. Difference between Summer and Fall Capstone 1 teams on "Got work Done?"

short break; the higher readiness of the Summer 1 students has no clear explanation.

Selected SWOT results are shown in Figures 7-9. The opportunities, like motivation answers in the last day exercise, were as varied as the projects, making them difficult to categorize. That also made the Awesomeness and Lameness scenarios highly varied. The other factors had clear trends. Most teams felt that they had technical and planning/program management strengths, as well as good teamwork and positive attitudes, expressed with words like discipline, focus, fearlessness and passion. Many teams worried about scheduling and time management, as well as poorly defined or creeping scope. Several teams specifically felt they did not know enough about coding. Threats included (lack of) access to needed resources, external disruptions to schedule and scope, bad results from work, and failure to get IRB approval, which threatened 8 of the 30 teams (!).

Selected LARD results are shown in Figures 10-11. Students felt that their technical management skills (such as scheduling, planning and teamwork) could head off many of the threats in the previous figure. They also had faith in attitude – determination, motivation and passion. Technical skill and the help of their advisors were mentioned a few times as resiliency resources. Finally, students feared schedule factors more than anything else could cause project failure. Interestingly, more teams feared schedule problems would bring them disaster than identified it as a threat. The same number of groups that saw bad results as a threat feared they would bring

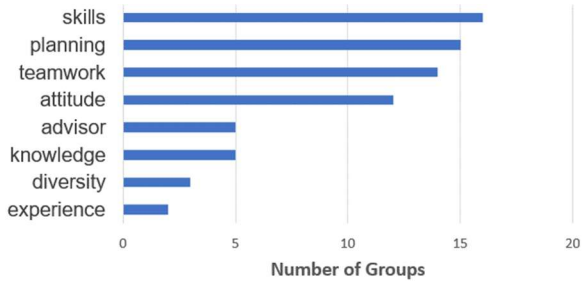

Figure 7. Self-identified team Strengths

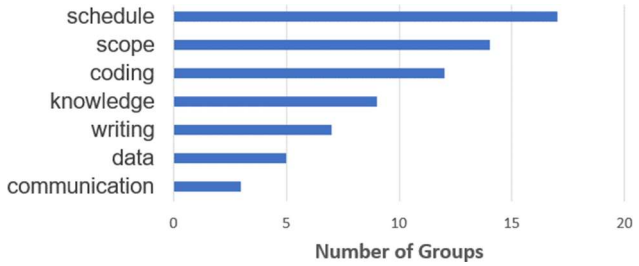

Figure 8. Self-identified team Weaknesses

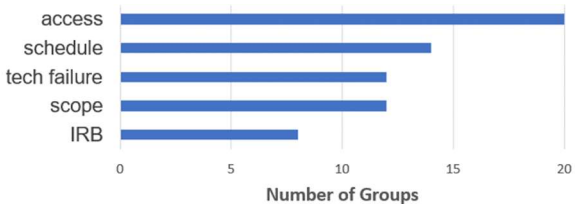

Figure 9. Threats

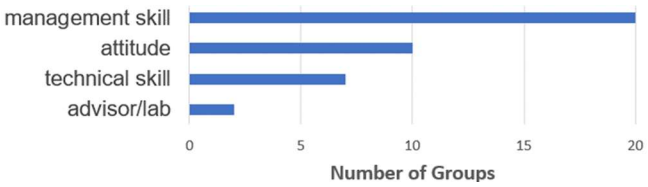

Figure 10. Resiliency factors

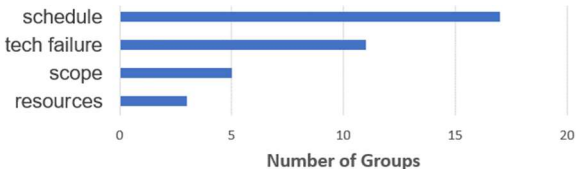

Figure 11. Disaster Scenarios

disaster. On the other hand, students seemed to feel that they could be resilient to the threats from resource access and scope problems.

Predicting Performance?

Is any of this predictive of success? A cross correlation was done, with some perhaps unsurprising results. Teams who identified writing as a weakness did significantly (p=0.04) less well on the final writing grade. The absolute difference was modest, as teams with writing deficiencies were mentored.[2] Identifying coding as a weakness, or schedule or technical problems as potential disaster scenarios, correlated with a lower final project grade. The correlation was significant (p=0.04) only for teams that identified *both* schedule and technical issues as potential disasters. Previously identified success factors such as work over the break, attitude, and teamwork did not significantly correlate with project success, at least in this sample.

Summary

A set of reflective exercises that span the gaps in a two-term capstone sequence are presented. They are easy to administer and should be usable in any two-term program. The results from two years of exercises provide some insight into student behavior over the breaks, as well as their perspectives on their teams' strengths, weaknesses, and vulnerabilities. Exercise results are correlated with project outcomes. Students' worries about writing, scheduling and technical failure seem to be justified, and are (or will be in future) a basis for corrective interventions.

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