Students' Reflections for Engineering Technology Capstone Course: Technical, Team Formation, and Communication Issues, Dealing with Ambiguity

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Abstract

Student input is insightful when reviewing an assignment, project, or otherwise engaging task within the framework of a required course. Most research dissects instructor observations and neglects to consider the student aspect and reflections as they relate to their experiences navigating the capstone course.

An undergraduate engineering technology program at a well-established land grant University in the Midwest requires students to complete a two-semester series capstone course. This course, as well as others in the same genre, works cooperatively with relevant industry to provide students with projects appropriate to their skills and abilities. The course is usually administered with the first part including a proposal or project definition, and the second part is implementation or solution phase. The intention of capstone courses is to apply knowledge acquired during tenure at college, provide students with an understanding of the industrial workplace, to expose the students to the ambiguity and uncertainty of engineering projects, and to hone their problem-solving skills within the context of their chosen career.

Student thoughts and concerns were examined using the lessons learned from an engineering technology capstone course that was provided as part of the final course assignment. Each team provided input that spanned technical issues to team-formation concerns and dealing with ambiguity. A qualitative content analysis was completed on the essays extracted from the final course assignment and analyzed for content, with the intent of sharing through scholarly work and dissemination. It is the authors' intent to inform practice of the various issues brought forth by the aviation technology students.

Introduction

Participating in a capstone course provides students with the opportunity to gain experience interfacing with the professional world as it relates to their chosen career, and to practice using the knowledge and skills acquired while pursuing their degree [1, 2]. Some may argue that an internship is sufficient for this purpose; however the capstone experience is guided by

faculty and structured to support learning. Further, administration may use the capstone course to assess the degree program' strengths and weaknesses with an amalgamated analysis approach [3]. Participating in capstone courses is also required by many accreditation bodies, for example ABET: "Graduates of baccalaureate degree programs must have a capstone or integrating experience that develops and illustrates student competencies in applying both technical and non-technical skills in successfully solving manufacturing problems"[4]. The activities required by the capstone course must provide "assurance that a college or university program meets the quality standards of the profession for which that program prepares graduates"[5].

The authors intend to provide a basic interpretation of student insight into this particular engineering technology capstone yearlong course. While capstone courses are used worldwide, it is best to see what lessons learned exist in one group of students and in future work expand to other capstone courses. The result of this work will be disseminated in order to provide insight of students' experiences at the end of their undergraduate studies and to further understand the students' development in the final states of their studies and if they are prepared for the challenges of the industrial workplace.

Background and Literature Review

Completed research on capstone courses generally goes to great lengths to examine instructor observations or results of assessment [6-8]. Few researchers consider the student aspect and reflections as they relate to their experience in the capstone course [9]. Review of relevant recent and past literature supports this assertion. In the case of Dunlap [9], students were required to complete a journal, take the General Perceived Self-Efficacy Scale [10-14] pre and post problem-based learning experience, and include a reflection in the final assignment. The intent of this work was to triangulate the materials that students were generating and synthesize the student experience. This particular paper finds that students experienced increased confidence, but some also were concerned about their lack of experience that became evident as they progressed through the project. The few others who considered the student perspective focused on team dynamics and the issues confronted by students who have little or no experience working in the team environment [6, 15].

Since the work that is done on the student perspective is limited, and data has been assimilated by observation, summation of reflections, or survey, we chose to use the Content Analysis Method [16]. This method is used to evaluate the Lessons Learned document generated at the end of the two-semester session as part of the final project document.

Content Analysis Method

The Social Science Research Council's Committee on Linguistics and Psychology sponsored a conference in content analysis in 1955 [16]. At this conference attending researchers discussed how best to analyze data that is provided via discussion, and written word. This means of analyzing written communication are what some consider the "essence of human behavior"[16]. Many refer to this method as Content Analysis, others use a slightly longer term of Qualitative Content Analysis [17], while others refer to this method as Quantitative Content Analysis [18] and refute the use of one singular method for analysis of reflective

essays. These were the two most common areas of observation considered important by the researchers at the 1955 conference [19].

The definition of qualitative content analysis by Schrier [17] is three-fold. The three components are a) systematic method, b) flexibility, and c) data reduction for interpretation. Using this interpretation and the information provided by Krippendorff [16], we have chosen to use the following pieces in order to interpret the Lessons Learned documents from the engineering technology course. Our research question is:

> *What do the students in the year-long engineering technology capstone course learn throughout the semesters based upon their projects, interactions with classmates, industry representatives, the instructor, and available resources?*

The data is collected, and the analysis will be done by subjecting the text provided in these sections to a variety of diagnostic means. These means are chosen based upon the material available in the documents, which is the flexibility of the method based upon the available data. Finally, the data will be reduced by running the text through word and phrase counters, and looking at frequencies. This data will then be used to reduce the smaller words, such as the, for, and like to further reduce the data per the method. Discussion and conclusions will ensue from the findings in the chosen methods.

Methods

Using the Content Analysis Method, all of the data was reviewed. The reflections were reviewed together and separately by students' cohort, developing inferences of the authors' intent by finally comparing the groups of reflections by reading, comparing, and then reducing the data.

Research Site and Participants

There are 40 students in each course. The majority of these students are 20 to 22 years old, with few exceptions of older students who are in the process of a career change or working toward job advancement. The instructor revealed that around 25% of the students shared that either they transferred from engineering programs because there was too much math, or they had the impression that they have a sedentary career in front of a computer. The balance of students in this class was not clear about why they chose the aviation technology program. Most said it was because "all my friends went to college." Many students in technology are interested in a hands-on approach of education vs. theoretical learning. Few of these students were exposed to problem-based learning and even fewer had the opportunity to manage their own time and projects.

Analysis Description

Initially the aggregate input from two distinct groups of students was examined for word frequency, and phrase frequency throughout. It is also worth noting that the students shared the same instructor, who applied the same pedagogical approach with identical course requirements. The data was examined together and then separately by semester.

This first step provides guidance to the authors on how to tailor a systematic methodology for examining the material. Use of the Qualitative Content Analysis methods suggest that

through the flexible nature of this kind of analysis tasks such as these are performed while developing a better idea of the content of the written text. Based on the findings of the word frequency analysis, it was deemed appropriate to perform a phrase frequency analysis, and then finally review this data using computer tools, including NVivo to perform qualitative analysis on text.

As with all qualitative analysis approach, the findings in this study reflect only this particular group of students in the environment previously described. However, it allows quoting Becker and Geer [20]: "The most complete form of the sociological datum, after all, is the form in which the participant observer gathers it; an observation of some social event, the events which precede and follow it, and explanations of its meaning by participants and spectators, before, during, and after its occurrence. Such a datum gives us more information about the event under study than data gathered by any other sociological method. Participant observation can thus provide us with a yardstick against which to measure the completeness of data gathered in other ways" (p. 28). To ensure more general and transferable results, greater number must be studied.

Results and Findings

The authors' went through the reflective essays by reading, developing inferences, and reducing the data to further our understanding of the students in these two independent courses. The interpretation of what students wrote as well as how they express themselves using technical language, formative terms regarding teams, and communication issues, and dealing with ambiguity are of primary focus in this findings section. The first section focuses on what was found as the reflective essays were read.

Reflective Essays

Reflective essays were reviewed and the path of these essays was deemed to be directed at a few topics. Students were given a very ambiguous assignment, leading to a broad open-ended assignment completion. Overall, students were focused on the team and what they were doing in the capstone course. They focused on time, sometimes defined as such, and in other instances by semester, or other similar terminology. Most of the verbiage was high level, and expressed issues with the project or the team, leading the authors into the stage of developing inferences based on what they read.

Developing Inferences

The essays focused on a few different matters, including an impossible scope, which alludes to student confusion or difficulty with an open-ended or ambiguous topic. While reviewing the first cohort's reflections, students seemed to have issues with planning, purchasing items with differing lead-time, and shipping requirements. These issues lead students to discuss issues with time management, and meeting deadlines. Many of the students suggested that if they could do the project over, their greatest focus would be to improve time management or scheduling of their time in project steps and completion. The teams identified communication as an issue with the members, which also led to comments regarding time management. Some teams lamented that their teams developed goals that were too large and unattainable.

The second semester's reflective essays focused on similar problems and issues, however they stated that they should have begun the project by investigating more means to make the final project instead of choosing one and creating issues with completion, cost, and assembly. They also pointed out that the sponsors were quite busy during the last months of their project, making completion difficult. This group of students mentioned that it would have been helpful had they considered plans for setbacks. Solving some of the problems they ran into was much harder because of the lack of forward planning.

While the inferences are leading, reducing the data into quantifiable observations aids in the interpretation and combination of concepts students found important enough to include in these reflective documents.

Data Reduction

The first step was to use the program available online at wordle.net. It graphically represents the content of text providing a word frequency analysis. The first as noted in Figure 1 shows the available aggregate data from the lessons learned section of the capstone course final report.

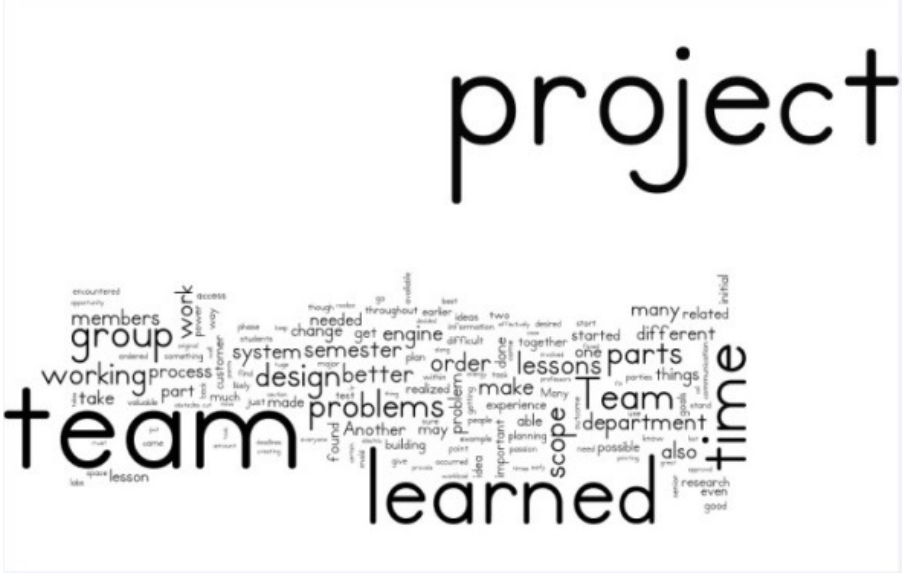

Figure 1. Aggregate Lessons Learned Data

Finding that this, in itself, did not indicate much other than project, team, learned and time were of importance in the text; therefore individual semester data was analyzed and compared to Figure 1. Group 1 of the available data is represented in Figure 2, while Group 2 is shown in Figure 3.

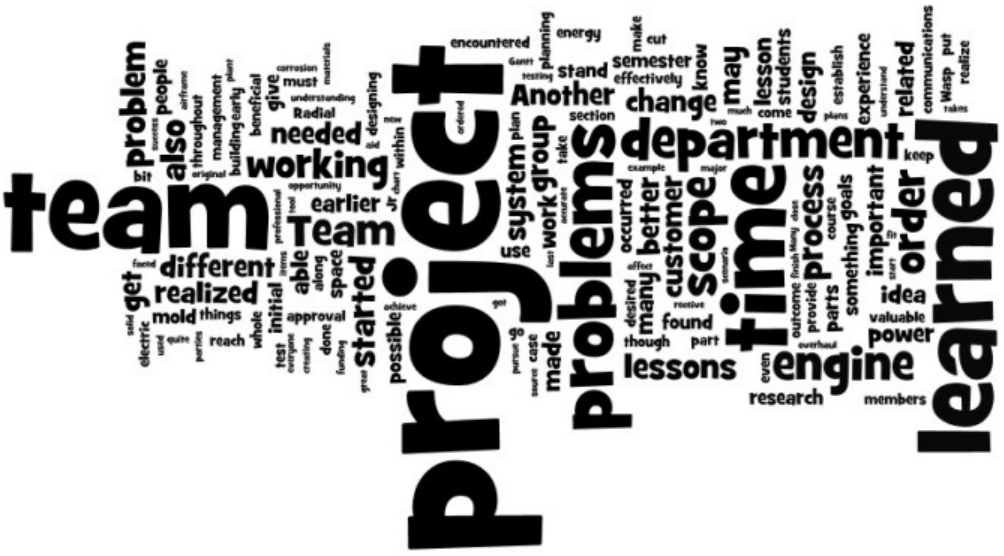

Figure 2. Group One Lessons Learned Data

Figure 3. Group Two Lessons Learned Data

These figures, as shown in Figures 1 through 3 are based on individual word frequencies. Many of the words although combined in Figure 1 show that the groups of students considered many of the same things important in their capstone experience. To further the examination of content, via content analysis a word count was executed to compare the students' word usage independently. Table 1 compares nouns and action words from both semesters. The words shown in this table are those that were the first nine words appearing the most in the word count of all essays.

Table 1. Comparisons of Groups by Word Count

Group 1	Group 2
Project	Team
Team	Project
Learned	Learned
Problems	Group
Engine	Parts
Department	Design
Working	Semester
Scope	members
Order	Working

Further analysis was done to evaluate phrasing that may be helpful in understanding the content of this data. Table 2 was developed to give a generalized comparison of phrasing for 5-word count phrases, and Table 3 for four-word count phrases. A generalization comparing the similarity of five and four-word phrases, such as "had to do it over" and "to do it over again," are found in both tables.

Table 2. Comparisons of Groups by Phrases (5 word count)

Group 1	Group 2
the time it takes to	the team learned
we had to do it	we did a good job
the team had to do	to do this project again
the scope of the project	that could be affected by
in order to compensate for	did a good job distributing
it is important	

Table 3. Comparisons of Groups by Phrases (4 word count)

Group 1	Group 2
had to do it	we were able to
to do it over	the team learned that
time it takes to	that could be affected
the team had to	team learned that communication
the team also learned	many lessons were learned
the scope of the	good job distributing workload
if the team	do this project again
in order to compensate	

Discussion

Comparing and contrasting graphic representation of the reflection essays provided the authors with an understanding of the groups' differences. The words that were most evident with the aggregate group are *project*, *team*, and *learned*, with the word *project* shown as the largest and even set off to the side showing the significant difference of the word. Reviewing the groups separately, both show the word *project* to be the most pronounced word, but not set off to the side. In the case of Group 1, the word *project* is not as differentiated by size or position as in the aggregate and Group 2. The words *team* and *learned* along with *time*, *problems*, and *department* in Group 1, and *team*, *learned*, and *group* in Group 2 provides the reviewer with a greater understanding of the significance of the project discussion in the essays. It became evident that these student teams found significance in things such as *team*, *learned*, *time*, and *problems*, essentially sharing how the projects affected the teams, how they learned, the lack of time, or time to complete the given problems. When reading the essays, this is what was found, not providing any additional insight other than the significance of the project to the team.

Further review through data reduction using word count and sharing the words side by side in Table 1 allows a comparison of word significance in the essays. *Team* and *project* are interchangeable as far as being the first two words and placed opposite one another in the comparison. The third word of significance is the same – *learned*. After the third word, the words no longer align, nor are they able to be easily compared. While reviewing Tables 2 and 3, the reviewers consulted Moon's [21] handbook and found that for a writer to exhibit deep reflection they must clearly state what was learned and changed. Using this definition of deep reflection, the statements in the tables, such as "in order to compensate for," "the team learned," "to do this project again, "to do it over," the team also learned," and "to do this project again" demonstrate deep reflection in the examined reflective essays.

The majority of students managed to achieve deep reflection as evidenced in the reflective essays. However, we question what is learned by the students that is technical, is formative from a team standpoint, and communicative. Assessment criteria were developed by Reidsema and Mort [22] that provide guidelines on how to analyze reflective writing. They provide an assessment and demonstrate use in the evaluations and determination of deep meaning in reflective writing. This examination follows:

Usage of Technical Terms

While technical words were used, due to the varying projects done in this capstone course, most are only used one or two times to describe student reflection on the projects, most likely explaining why the most commonly used words include *project*, *team*, and *learned*, as each of those is common to all of the projects. Another reason was that the students concentrated mainly on project management side of their efforts, relying on drawings, tables, and graphs to communicate other aspects of the projects. The students were comfortable with their technical knowledge, because this is what most programs are successfully emphasizing. The project management side and ambiguity are less familiar to the students and caused more confusion.

Team Formation

Team formation is critical to the successful completion of any project. In this case, student reflections say something about "the group" or "the team." General discussion in the essays provided a distinct impression that the team members, while good friends in some cases or people not getting along in other situations, were able to work together and develop a functional team. Review of the essays revealed that the students defined a "sound" or "functional" team, where the members agree on a project plan and work toward that end. Another lesson learned was that it is not always easier to work with friends. One team had an issue with meeting more than once a week, resulting in team formation issues. They overcame that by being careful with what they did, and when and how they interacted with others. Other teams had issues with becoming teammates with "non-friends" and the issues that arose due to motivation and capabilities. Finally, a couple of teams pointed out issues with low productivity and motivation due to conflicting priorities as they neared the end of their senior year.

Communication Issues

Review of essays brought forth the issue of communication, or lack thereof. Many teams had communication issues with team members unknown to one another up on team formation. Their communication style and methods were so different in some cases that rifts in the team formation became evident and had to be worked out. Again, the programs concentrate more on technical skills and less on project management, where many tools are available to establish, use, and improve communication. One of the examples could be meeting minutes. The students met on a regular basis, but rarely wrote their discussions, deadlines, responsibilities, and plans down. As a result, many details, as students say, "fell through," were never done or finished with a delay. The project was delayed and caused confusion and anxiety. The results of this study demonstrate that planning and communication are the cruces of successful teamwork. Often this population of students is neglected or combined with other much larger study populations, describing the analysis of the capstone reflections provide support that engineering technology students have similar issues as their peers in teamwork. When examining the differences between engineering technology students and other student groups in STEM this is not always the case.

Conclusion and Future Directions

Overall, students in an engineering technology capstone course learn that planning, and learning how to communicate with one another are critical to the success of a team. These students produced deep reflections and, while not using many technical terms, did share information regarding the formation of their teams and growth in personal interaction, which includes modes of communication. While examining the word counts, comparing them from one group of students to another, a common concern regarding communication and collaborative skills emerges. Students do not exhibit these skills and gain an understanding of their importance in teamwork situations.

The end of the semester, senioritis [23] becomes an issue affecting motivation and completion of capstone projects. This revealed that it is imperative that serious project work

takes place earlier in the semester to assure that it is not affected by conflicting priorities and issues caused by the end of the semester for graduating seniors.

The study also suggests that learners be exposed to project management methods and tools earlier in their tenure at college. It is crucial to offer more project- and problem-based courses with a greater level of ambiguity to prepare students for the workplace.

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