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Engineering Technology Students: Do they approach capstone courses differently than other students?

Anne M. Lucietto
Purdue University, lucietto@purdue.edu

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Anne M. Lucietto[1], Andrew Scott[2] and Frederick Berry[1]
Purdue University[1]/Western Carolina University[2]

Using data collected from students in engineering technology, engineering, and other areas such as computer science a comparison of student reactions to the capstone course are coded and sorted. Using content analysis methods, the researchers compare and contrast the various student groups and their reactions to assigned capstone projects. They are also able to assess student interaction with faculty and industry mentors. Researchers strive to learn more about these various student approaches to the capstone experience and to further our understanding of best practices in capstone courses.

This paper follows an introductory work intended to begin investigation into the results of a multi-institutional collaboration intended to identify best practices, and improving teamwork skills[1]. This work uses the data provided within two senior capstone courses in STEM fields in particular engineering technology and computer science. A group of participating institutions is involved in an iterative process of gathering data, changing instructional design, and then improving the senior capstone programs in each school. It is the group's intent to disseminate these findings throughout the project as noted in this paper, and in the future, as course materials and practices are modified, assessed, and improved. At this time the data collected from a larger capstone course is compared to existing published data by others and also to data provided by one of the group partners prior to use of the data collection tool.

CATME Data Collection Tool[2]. This is a tool for managing student teams, specifically aiding instructors in determining and utilizing best practices in student team management. The training and tools made available by the project supporting CATME is based on current literature on team work as well as independent empirical research in these areas. CATME is a project that was begun in 2003 through the development of an instrument focused on peer and self-assessment called the Comprehensive Assessment of Team Member Effectiveness. The system enhances team development by creating accountability and feedback for team members, suggesting that team members and instructors have a positive team learning experience.

Capstone Courses – Multi Institutional Collaboration. The previous work by the multi-institutional collaboration identifies the current work done in many capstone courses including those factors that are measureable[1]. Those measurable factors[3] are included in CATME, thus the authors have chosen to use note taking [4], filing [5], goal setting[6,7], and other reflective open ended

input [8] to assess student progress. The approach used in an earlier paper included a comparison of the reflective data, this work will focus on the differences of engineering technology students from others in the multi-institutional collaborative group.

Early Project – Examination of First Semester Data. In the capstone courses examined in the first publication[1] project, industry and academic mentors guide students through the experience. The compilation of CATME data from the first semester revealed that students feel confused and abandoned. Suggesting that engineering technology students require the additional guidance of well-trained and dedicated industrial and academic mentors for the self-confidence and successful completion of the assigned team projects.

Research Question. The analysis of teamwork learning within the capstone programs is the best way to provide supporting evidence for change within these courses. Using the course feedback is an effective means to encourage change in a variety of student populations. The question that continues to be asked as we strive to grow this project and its findings is:

> *In what ways can and do Technology Capstone courses impact the Teamwork Skills of their students?*

Gathering Data. Collaborators in the multi-institutional group have not all adopted CATME for team evaluation. They do plan to do so in the fall term following initiation of this project. Some of the participating institutions have provided insight into their observations in preparation for use of CATME in their programs. At this point Purdue University – Main Campus provides CATME data, the other institutions provide empirical data about the performance of their capstone teams.

Purdue University (PU) Data From Data Collection Tool vs. Others as Published

The CATME[2] data collection tool was used at each gate, which are periods of time during the semester. There are three of these periods during the fall and spring terms where mid-course assessment is completed. The data was used to determine if students were satisfied with their team building experience both on an individual and team basis.

Individual Data. Throughout the capstone course the CATME Peer Review measurement tool is used to collect peer and self-evaluations of each team member's contributions. These contributions are assessed against five different teamwork dimensions [9,10 11 12]. These five teamwork dimensions are:

C Contributing to the Team's Work is being able to add value to your team's work/project. This dimension indicates of students are completing individual portions of the work in a timely manner.

I Interacting with Teammates refers to the way individuals communicate within their teams. Each team member is encouraged to provide their opinion, which allows them to provide input and feel that their thoughts are respected.

K Keeping the Team on Track is similar to being a timekeeper. To help keep the team stay on schedule, transparency in the teams' expectations provides a means for the individual to encourage the team to complete tasks on time.

E Expecting Quality is takes team expectations to a higher level, and encourages collaborative work to obtain the best outcomes within the requirements of the course.

H Having Relevant Knowledge, Skills or Attributes (KSAs) refers to the base knowledge of individual team members.

CATME student data for the five teamwork dimensions for both self and peer, as well as peer only ratings, were aggregated and averaged. This provides a team rating for each of the gates or points of data gathering, see Tables 1 and 2. The self-rating was removed and the peer ratings aggregated and averaged to obtain a team-rating for the same period. In all cases, the scoring is done on a 5-point positive Likert Scale.

Table 1. The Five CATME Teamwork Dimensions, Gates 1-3

Variables	Evaluations	Gate 1 Mean	Gate 1 SD	Gate 1 Median	Gate 2 Mean	Gate 2 SD	Gate 2 Median	Gate 3 Mean	Gate 3 SD	Gate 3 Median
C	Self & Peer	4.288	0.480	4.333	4.297	0.563	4.500	4.302	0.604	4.333
I	Self & Peer	4.429	0.409	4.500	4.365	0.478	4.500	4.360	0.569	4.500
K	Self & Peer	4.293	0.466	4.333	4.328	0.550	4.500	4.388	0.565	4.500
E	Self & Peer	4.361	0.438	4.500	4.329	0.514	4.333	4.357	0.523	4.500
H	Self & Peer	4.456	0.421	4.500	4.395	0.463	4.500	4.388	0.519	4.500
C	Peer	4.284	0.568	4.333	4.251	0.681	4.333	4.274	0.733	4.333
I	Peer	4.401	0.494	4.500	4.332	0.591	4.500	4.302	0.688	4.500
K	Peer	4.274	0.570	4.333	4.269	0.653	4.400	4.364	0.668	4.500
E	Peer	4.328	0.526	4.333	4.286	0.605	4.333	4.330	0.620	4.500
H	Peer	4.444	0.497	4.500	4.363	0.564	4.500	4.361	0.637	4.400

Table 2. The Five CATME Teamwork Dimensions, Gates 4-6

Variables	Evaluations	Gate 4 Mean	Gate 4 SD	Gate 4 Median	Gate 5 Mean	Gate 5 SD	Gate 5 Median	Gate 6 Mean	Gate 6 SD	Gate 6 Median
C	Self & Peer	4.192	0.632	4.250	4.206	0.705	4.250	4.298	0.690	4.500
I	Self & Peer	4.311	0.542	4.500	4.335	0.536	4.500	4.285	0.611	4.500
K	Self & Peer	4.239	0.551	4.286	4.247	0.636	4.333	4.284	0.616	4.333
E	Self & Peer	4.289	0.515	4.429	4.297	0.579	4.500	4.298	0.613	4.333
H	Self & Peer	4.280	0.587	4.500	4.257	0.650	4.333	4.308	0.640	4.500

C	Peer	4.123	0.748	4.333	4.128	0.833	4.333	4.232	0.806	4.500
I	Peer	4.259	0.645	4.333	4.276	0.623	4.333	4.225	0.731	4.333
K	Peer	4.176	0.679	4.333	4.184	0.746	4.333	4.225	0.719	4.333
E	Peer	4.225	0.629	4.333	4.229	0.691	4.333	4.251	0.712	4.333
H	Peer	4.229	0.685	4.333	4.205	0.770	4.333	4.243	0.750	4.333

Peer-appraisals of team performance have been found to be lower than self-appraisals of the same[13]. Davis et al [14] suggested that mean self-rating was higher than mean-peer ratings. These results are confirmed in both Tables 1 and 2. Figure 1 shows the data comparison for Gate 3, and Figure 2 the data comparison for Gate 6 at the end of the first and second semesters. This allows for adjustment of data and the comparison of students more accustomed to use of the data tool. The comparison supports the findings of both Davis et al[14] and Miller and Cardy[13]. However, this data shows a greater difference between the data in Gate 6 at the end of the capstone series than at the end of the first semester.

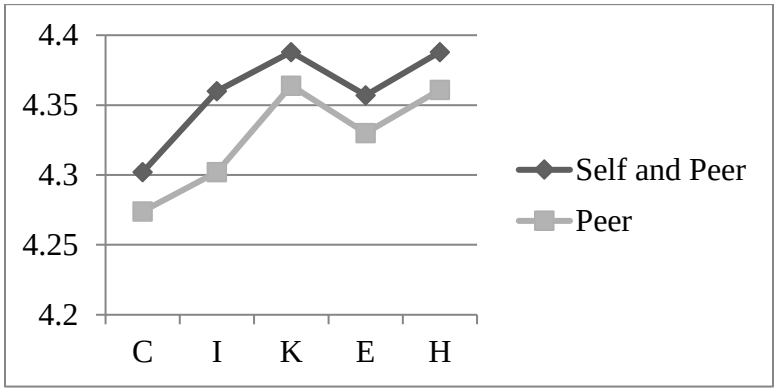

Figure 1. Comparison of Self and Peer Data (Gate 3 Mean)

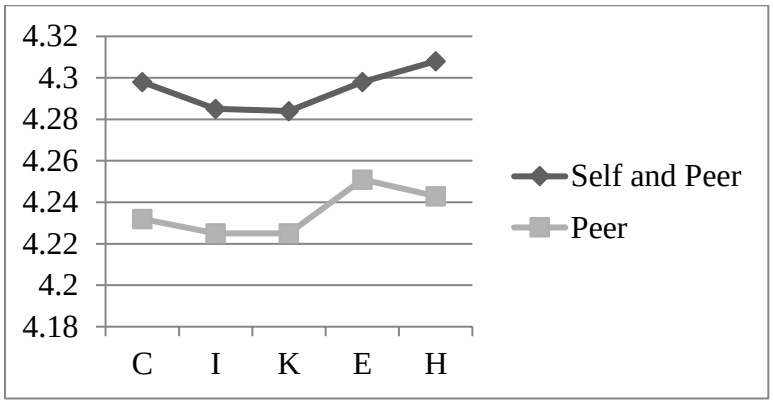

Figure 2. Comparison of Self and Peer Data (Gate 6 Mean)

Team Data. The CATME Peer Review measurement tool also includes three questions where the student measures the team and not each other. [10] These three questions are:

Q1 I am satisfied with my present teammates
Q2 I am pleased with the way my teammates and I work together
Q3 I am very satisfied with working in this team

The data from CATME for each of these three questions was averaged and aggregated. This was done to summarize the team data and obtain a team rating for each question at the six gates or data collection periods throughout the course. This data is found in Tables 3 and 4 using a 5 point Likert Scale.

Table 3. The Three CATME Student Measures of Team, Gates 1-3

Variables	Gate 1 Mean	Gate 1 SD	Gate 1 Median	Gate 2 Mean	Gate 2 SD	Gate 2 Median	Gate 3 Mean	Gate 3 SD	Gate 3 Median
Q1	4.504	0.661	5.000	4.324	0.836	5.000	4.229	0.864	4.000
Q2	4.411	0.737	5.000	4.281	0.860	4.000	4.198	0.956	4.000
Q3	4.440	0.759	5.000	4.252	0.885	4.000	4.183	0.959	4.000

Table 4. The Three CATME Student Measures of Team, Gates 4-6

Variables	Gate 4 Mean	Gate 4 SD	Gate 4 Median	Gate 5 Mean	Gate 5 SD	Gate 5 Median	Gate 6 Mean	Gate 6 SD	Gate 6 Median
Q1	4.207	0.904	4.000	4.147	0.864	4.000	4.125	0.914	4.000
Q2	4.145	0.979	4.000	4.063	0.913	4.000	4.117	0.919	4.000
Q3	4.103	0.963	4.000	4.028	0.896	4.000	4.086	0.956	4.000

Western Carolina University (WCU)

Since the fall of 2014 WCU has had 60 students in the yearlong capstone experience. At WCU, capstone students work in pairs over two semesters. In a typical semester, there are between 10 to 20 student pairs. The faculty decide on a list of project descriptions from which students rank their top choices. On this basis the pairs are assigned one of four faculty supervisors. By utilizing pairs, the intention is to provide the experience of interdependence while maximizing accountability. With pairs, each student has to be involved in multiple facets of the project and thus cannot narrow their focus and skill application to a small subset of the solution domain.

At the start of each semester the pairs will develop a proposal report of approximately 800 to 1500 words featuring a problem statement, requirements specification, the proposed solution, a plan for testing, and a schedule of completion. For the remainder of the semester the pairs will meet bi-weekly with their faculty supervisor and submit a 200 word (minimum) progress report. At the end of the semester the pairs are expected to demonstrate a working product, conduct a 20 minute technical project presentation and submit their source code along with a final report. The final report documents the project in a reflective capacity.

Success of the paring depends on finding a good match in personality, energy and technical ability. When mismatches occur this can negatively impact the five (CIKEH) dimensions measured by CATME. Where mismatches occur we have seen instances of free riding [1], taking over [15] or interpersonal conflict. From a grading perspective many of the issues can be mitigated by discussion and assigning individual grades to each member of the pair. However, this cannot fix the negative the impact on team productivity and learning. In extreme cases, a last resort has been to split the students and make them work alone. Besides the reasons stated above, there are a number of other reasons we allow students to conduct their capstones as a solo activity. Students that are deemed to have difficult personalities, low motivation or are low achieving may be encouraged to work alone. Another reason is project choice. Occasionally a student proposes their own project, which gains little interest from other students. A final reason is that one of the pair does not complete the semester (for reasons not related to the capstone), or choses to leave the university. Table four below provides a statistical snapshot of our capstone program, its pairs, solo works and the board reasons that some pairings did work out.

Table 5. Students in Capstone at WCU from Fall 2014 to Spring 2017

Category	N
Students:	60
Paired from the start :	23
Solo from the start:	14
Solo because of team issues:	4
Solo because partner left the university:	3
Solo because partner did not completed semester (academic performance in all courses):	1
Project topic changed due to student difficulty	1

Qualitative Data From WCU. [1,15] The data provided by WCU is qualitative in nature. They are beginning to use CATME in the fall 2017 semester, while to date they have empirical data for past semesters consisting of the final reports submitted by each team at the end of the semester.

At WCU each capstone team is required to produce a final report which consists of a technically oriented reflection regarding the work they did on the project. For this initial evaluation the final project reports was obtained from eight pairs (not solo workers) chosen at random from capstones occurring from the fall 2015 to spring 2015. While the results are not earth shattering, they begin to show how teams of two interact, the interaction of the students, as well as their thoughts about a capstone related to their career path. While this is a contrast in how the capstone is formed and students interact with larger capstone groups such as at Purdue University, the student experience at WCU and other institutions will provide a rich understanding of team building and interaction throughout their solo and pair capstone experience.

Of the eight samples from WCU, only seven provided a final report with a reflective essay. These essays were reviewed using a word count tool[16], and techniques used in Content Analysis [17-20] methods. The results of this analysis follow:

Word Count Tool. A free word count tool [16] was used to see what the frequency of words used. This technique often provides what students are thinking. Table 5 shows the top five words as they appear in the seven analyzed reflective essays. These words share some of what the students were thinking. Based on those findings it is necessary to use Content Analysis Methodology [17,19,20] to further delve into the reflective pieces written by the students.

Table 6. Top Four Words In Essays

Word Use	Frequency
Semester	3%
Project	3%
Application	2%
More (time)	1%

Content Analysis Methods. This methodology is used to review the qualitative data provided by WCU and previously to analyze data provided by Purdue [1]. This allows the researchers to examine data to see if there are relevant patterns or information that is given by the students in this project. This methodology is often used due to its use in this type of data. In this paper the researchers are able to identify student thoughts and how they relate to other capstones, regardless of team composition. Rather thoughts expressed by the students relative to the course in which they interacted.

Student Response to the Capstone. The students at WCU are in computer science, their capstone consists of a team of two. While this differentiates them from students in other programs it provides a means to look at the similarities and differences between the two populations groups.

From the seven reflections, students shared the following:

> They had issues adhering to their time frame – often completely ignoring it. In the earlier study, the Purdue students had similar issues focusing on what should be done when.
>
> Students were rather candid about either finishing goals faster than they thought or much slower. Most often these students shared that the issue was their skills in the software that they chose for their project. If they were familiar with the software, they said that and commented on their successful completion of their goals. If not, they suggested using a

software they were familiar with to complete the project on time and to meet the goals they set forth up on the start of the project.

Others had issues with getting their project to work on a desired platform and most lamented over the fact that they did not formally test their work. Suggesting that this was an issue in the final execution of the program.

While these observations are different from those found in CATME data in the first paper, students clearly have issues with adhering to the timeline regardless of their institution. CATME elicits more emotional response due to the interaction with the classmates, therefore the final data from both programs, as it stands now, would be different. It was of interest to see that students find the timing issue important in both universities.

Discussion

The data presented here from Purdue University shows the responses of the students using CATME for the entire semester. Often observed by faculty is a change in motivation and interest in the capstone project semester to semester. Students that have lagged in their work, and in general have fallen behind, will often charge forward with renewed energy as they are attempting to salvage a grade or they share that they see the value of the capstone to their careers. A second group often observed have done well through the first semester and continue their quest to do well and learn as much as they can through the completion of the second semester of the capstone. While the last group has generally done well in the first semester and becomes afflicted with "senioritis" [21], and are challenged by their lack of motivation.

Overall the data presented shows that the mean self-ratings were higher than mean peer ratings, thus confirming the findings in similar research [13,14].

Western Carolina University (WCU) observations include those in the computer science (CS) program. The CS program at WCU is relatively small, owing to a low but growing enrolment it consists of four faculty members during the periods under observation. Students are paired up early in the semester and given projects relevant to their future career. Because we are a small department, and each faculty members has very likely taught each capstone student at least once, and often more, we are able to assess characteristics and compatibility of our students with detailed insight. It is for that reason that since the fall of 2015 only four of our 23 capstone pairs broke up due to issues within the team. At larger institutions this level of familiarity cannot easily be archived and it's for these reasons tool such as CATME's Team Maker [2] exist.

However, despite breakups because of teamwork issues being statistically uncommon, their causes are known and are routed in partner compatibility. For example, in the capstone program it has been known for some students to blossom in their abilities and motivation and thus differ greatly from their partner in speed and ability. Other times, the most able of the pair undervalues

the work of their partner, this causes friction and negatively impacts the motivation and therefore achievement of both students. However, while the majority of WCU's pairs remain together and work harmoniously and without issue, at some point all faculty members have experienced friction, differences in ability, a student taking over and free riding in their pairs. While often not serious enough to break up a pair, the issue is mitigated though individualized grading and verbal warnings.

While WCU do not currently use CATME they will be implementing it from the fall of 2017. The collection, statistical analysis and sharing of such data though tools such as CATME will provide valuable insights that can be used to spot patterns and problems earlier. This will allow improved pair selection, remedial processes and related capstone procedures.

Conclusion

Data collection continues and the researchers are constantly looking for aberrations in the data or findings that suggest new and different ways to encourage learning of teamwork skills. The variability of programs provides a means to examine the differences and similarities in the programs and substantiate changes that may be suggested in the delivery of the programs. As in the case of WCU, they have observed and collected reflective data until they implement CATME for data collection purposes. The contrast of this program, the findings in the reflective statements shows that while the data collected is different, enough information is present to provide and understanding of what students see in the capstone experience.

Regardless of the program, students struggle with the timing of work to be completed, and the differences in self and peer evaluation. In the case of PU, the data supports previous findings showing that self-evaluation exceeds peer evaluation, regardless of timing within the semesters. The differences became more pronounced as the semesters progressed. In the case of WCU data, even though a different type of data, students mention semester and project with some frequency. When reviewing the actual verbiage they are concerned with project timing and completion of the assigned task.

The work done for this part of the project confirms the similarities of student concerns regardless of the course format and team structure. Further studies and data review will be needed to confirm the consistency of this finding. As the project continues and more data is collected and assessed, it is anticipated that insights into student development of this type will provide a platform for practitioners to incorporate the skills valued by employers into their programs.

Bibliographic Information

1 Lucietto, A., Scott, A., Connor, K. & Barry, F. Initial Survey of Engineering Technology Capstone Courses and Teamwork building Using CATME in *125th Annual ASEE Conference.* (ed ASEE).
2 *CATME Smarter Teamwork*, <http://info.catme.org/> (2017).
3 Lynn, G. S. & Reilly, R. R. Measuring team performance. *Research-Technology Management* **43**, 48-56 (2000).

4 Dixon, N. M. Organizational learning: A review of the literature with implications for HRD professionals. *Human Resource Development Quarterly* **3**, 29-49 (1992).

5 Linhoff, J. & Settle, A. in *Proceedings of the 4th International Conference on Foundations of Digital Games.* 121-128 (ACM).

6 Larson, C. E. & LaFasto, F. M. *Teamwork: What must go right/what can go wrong*. Vol. 10 (Sage, 1989).

7 Locke, E. A. & Latham, G. P. *A theory of goal setting & task performance*. (Prentice-Hall, Inc, 1990).

8 Koh, E., Hong, H. & Seah, J. in *Advanced Learning Technologies (ICALT), 2014 IEEE 14th International Conference on.* 264-266 (IEEE).

9 Sanger, P., Ferguson, C. & Stone, W. Integrating Project Management, Product Development, and Senior Capstone into a Course Sequence that Creates New Products and Patents for Students in 117th *ASEE Annual Conference, Austin, TX*.

10 Lucietto, A., Scott, A., Connor, K. & Barry, F. Initial Survey of Engineering Technology Capstone Courses and Teamwork building Using CATME in *125th Annual ASEE Conference.* (ed ASEE).

11 Albano, G., Capuano, N. & Pierri, A. Adaptive Peer Grading and Formative Assessment. *Journal of e-Learning and Knowledge Society* **13**, 147-161 (2017).

12 Berry, F. C. & Carlson, P. A. Assessing Engineering Design Experiences using Calibrated Peer Review. *International Journal of Engineering Education* **26**, 1503-1507 (2010).

13 Miller, J. & Cardy, R. Self-Monitoring and Performance Appraisal: Rating Outcomes in Project Teams. *Journal of Organizational Behavior* **21**, 609-626 (2000).

14 Davis, D. *et al.* Assessing team member citizenship in capstone engineering design courses. *International Journal of Engineering Education* **26**, 771 (2010).

15 Kropp, M., Meier, A. & Biddle, R. *Teaching Agile Collaboration Skills in the Classroom* in *2016 IEEE 29th International Conference on Software Engineering Education and Training (CSEET).* 118-127.

16 Tool, W. C. *Word Count Tool*, <https://wordcounter.net/> (2017).

17 Bangert-Drowns, R. L., Hurley, M. M. & Wilkinson, B. The Effects of School-Based Writing-to-Learn Interventions on Academic Achievement: A Meta-Analysis. *Review of Educational Research* **74**, 29-58, doi:10.3102/00346543074001029 (2004).

18 Hsieh, H.-F. & Shannon, S. E. Three approaches to qualitative content analysis. *Qualitative health research* **15**, 1277-1288 (2005).

19 Krippendorff, K. *Content analysis: An introduction to its methodology*. (Sage, 2012).

20 Neuendorf, K. A. *The content analysis guidebook*. (Sage publications, 2016).

21 Manning, C. "Senioritis:" An Analysis of Academic Motivation and Burnout in College Students through the Lens of Positive Psychology. (2011).