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Initial Survey of Engineering Technology Capstone Courses and TeamworkBuilding Using CATME

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Dr. Lucietto has focused her research in engineering technology education and the understanding of engineering technology students. She teaches in an active learning style which engages and develops practical skills in the students. Currently she is exploring the performance and attributes of engineering technology students and using that knowledge to engage them in their studies.

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I am an experienced computer science lecturer, software engineer, mobile applications developer and researcher with a flair for creativity and visual design. At Western Carolina University I have taught a diverse range of topics under the umbrella of computer science and supervised undergraduate research projects (capstone). My current research interests revolve around computer science education, best practices in team formation and assessment of work, the visualization of programming concepts, and mobile applications. I have been programming in the OO and imperative paradigms for over 15 years. Since 2006 I have been lecturing and tutoring computing subjects. In addition to my teaching record, I have also gained significant experience leading the research and development of commercial mobile applications on the Android and IOS (iPhone) platforms for a specialist business support center (CEMAS) based at the University of South Wales in the UK. In 2010 I successfully defended my PhD thesis, which focused on developing and using dynamic, interactive visualization techniques and a scaffolding pedagogy to teach the concepts and skills of programming to novices more effectively. As a result of this work, I have developed a unique visual programming environment, website and pedagogy which I integrated into the teaching of programming at three universities. This research has also received significant attention from high schools and universities globally. It has been presented at both a national and international level. I have also used it in outreach activities to promote the subject of computing in both in Wales and the Smokey Mountains region.

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Abstract

This paper represents a first step in what is to become a multi –institutional initiative focused on identifying best practices for developing and improving teamwork skills within the Capstone experiences of engineering, technology and computing programs. Teamwork in this paper is defined and measured as the dimensions measured by the CATME Peer Review [1], which is currently used by thousands of technology and engineering instructors and institutions worldwide. The CATME Peer Review measurement tool is used to collect self and peer evaluations of team members' contributions on five different teamwork dimensions [2]. These teamwork dimensions are 1) pose the knowledge, skills, and abilities to help the team; 2) expect quality work from the team; 3) keep the team on schedule; 4) positive interactions between teammates to help the team; and 5) all team members contribute to the team's work and success. Pung and Farris[3] used CATME in a one semester junior level design class and reported a "significant improvement" in student behavior when compared to the old system of peer review. A workshop was developed to assemble all the participants, and develop a systematic method of evaluating teamwork building using CATME. All the participating schools and faculty will be testing changes in their Capstone courses and sharing the results of this analysis, in teamwork skills, with their colleagues.

Introduction

The goal of this paper is to present the motivation and initial findings of what is to become a multi-institutional collaboration to develop and implement best practices for assessing and improving teamwork skills within the capstone experiences of engineering, technology and computing programs. Little current research has been published focused on building teamwork skills in technology Capstone courses. For engineering technology students only older reference works exist for teaching engineering design [4], selecting types of Capstone courses [5], and satisfying industrial partners [6]. The participating schools and faculty will be implementing CATME in their Capstone courses and share the results. It is anticipated that the results of this iterative process will result in changes in instructional design that improve student teamwork skills within their universities.

First Workshop

To further understand the capstone ethos of the collaborating institutions a workshop was held in the fall of 2016. The faculty that manage, support, and influence the Capstone programs at their respective institutions attend this workshop. These faculty are from diverse institutions located in different parts of the country including the upper Midwest, Northeast, Central Atlantic, and South regions. These institutions are:

- Western Carolina University
- Prairie View A&M University
- Rensselaer Polytechnic Institute

- Farmingdale State College School of Engineering Technology
- Purdue College of Engineering, School of Engineering Education
- Purdue Polytechnic Institute, School of Engineering Technology

From this workshop and follow-up conversations a high-level view of "our" capstone programs and points of agreement were developed:

High-Level View

- Capstone programs are one semester and two semesters long
- Capstone programs are single major and multiple major
- Capstone programs have enrollment from 20 to 200 students per course
- Capstone programs have four to 20 academic mentors per course
- Capstone programs do and do not charge clients

Points of Agreement

- All participants agreed that they were interested in learning more about each other's programs and how the universities form Capstone teams.
- All participants agreed that they should use CATME as a common tool for team building assessment and planned to use training made available by the manager of the program.
- All participants agreed that students would benefit from more teamwork training. Most use some teamwork training; the amount and choice of training vary from institution to institution.
- All participants agreed that reviewing the data from at least one Capstone course was necessary to start this collaboration

Why CATME?

CATME is a system of web-based tools faculty can use to manage student teams. Started in 2003, CATME has four different tools faculty can use, they are, CATME Team-Maker, CATME Peer Evaluation, CATME Rater Calibration, and CATME Meeting Support. In addition to these tools, CATME as a set of teamwork training modules that faculty can use for teamwork training.[7]

In the following literature review, measurable factors have been identified that affect student team performance. CATME has features and tools that enable the collection of multiple peer evaluations each term to provide both individual and team learning data, which can be analyzed.

Literature Review

The following keywords were used to start the literature review; engineering-technology, teamwork, skills and students. The search was limited to scholarly (peer reviewed) journals published between January 1995 and December 2016. During the review process, additional papers, conferences, books, websites, etc. were identified and reviewed due to the quality of their citation.

Measurable Factors

Lynn and Reilly and other have identified measurable factors that affect student team performance[8], which includes note taking[5], filing [9] and goal setting (included in CATME) [10] [11, 12]. In addition, Koh, Hong and Seah propose a chat related data collection process and an analytic framework "using manual and semi-automated text analysis, event log analysis as well as survey methodology" to measure team effectiveness[13] (CATME has implemented peer to peer written explanations of peer evaluations).

Borrego identifies four different team effectiveness constructs described in engineering education literature, all which describe potentially important but different activities or output measures to record for the team as a whole [14]. Borrego's constructs are all substantially encompassed by the working definitions of the five CATME rating dimensions.

Salas says teamwork measurement is difficult because it requires multidimensional constructs and team behavior is elusive and dynamic [15]. Salas also postulates seven task or team specific knowledge, skill or attitudes related to teamwork effectiveness which apply to effectiveness as a team member or for team performance [15]. Salas's seven teamwork effectiveness principles map onto the five CATME teamwork rating dimensions (and Salas and his research team worked with the CATME research team for several years helping develop our CATME training tools).

For this study, the team is relying on the five-dimensional teamwork behavior CATME rating constructs, multiple types of Frame of Reference training [16] and the process of collecting multiple peer evaluations each term to provide both individual and team learning data.

Research Question

This research focuses on studying teamwork learning while working to find the best practices in this area.

We seek to answer the following broad question:

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

Teamwork

Teamwork in this study is defined and measured as the dimensions of teamwork assessed by the CATME Peer Review behavioral measurement system, currently used by thousands of technology and engineering instructors and institutions worldwide. These teamwork dimensions are:

- Having relevant knowledge, skills or attributes (KSAs) refers to the base knowledge of individual team members. It means having the required KSAs to solve the problems at hand, or being willing to learn or adapt the KSAs an individual lack.

- Contributing to the Team's Work is being able to add value to your team's work/project. It includes completing your portion of the work in a timely fashion.
- Interacting with teammates refers to the way individuals communicate within their teams. Encouraging every team member to give their opinion, allowing their voice to be heard, and respecting their ideas is the essence of good interacting.
- Keeping the team on track is similar to being a timekeeper. When an individual is aware of the timeline for the project and makes sure their team meets the required steps in time, they are helping the team stay on track.
- Expecting quality is taking expectations to the next level and working collaboratively to produce the best possible team outcomes within the constraints of their course.

Preliminary Findings from One Capstone Course

The participating schools will implement CATME in their Capstone courses and use an iterative process of data collection; data-analysis; results-sharing; collective-discovery; and feedback into courses to improve student teamwork skills within their universities. At this point in this iterative process, results from one university's CATME survey of 147 students were used to further our understanding of the content of these evaluations.

Content Analysis

Content Analysis [17-19] was used to evaluate the data from the university participants, when applicable, and the results of the CATME administration. This methodology provides a means to examine data to determine if there are relevant patterns in their responses. Explanations were coded, looking for particular words and phrases used to answer the research question. This method of analysis is frequently used because of its flexibility and ability to be used regardless of what is found in research data.

Content Analysis Findings

Using content analysis methods, the following issues were identified:

Time and Scheduling

- Special arrangements were made for trip to industrial partner, person that needed the accommodations did not participate.
- Students tell others in team they do not have time to work on projects, usually before a deadline.
- Student participation is not even and at least one student is under performing
- Individual students have issues with attendance.
- Individual team members refused to provide input on the project because they "had other assignments for other classes to work on."

Motivation

- Individual student motivational level changed, student not motivated to work on class project.
- Other students always have excuses for lack of team contribution.

Communication

- Communication among group members does not work, resulting in limited communication or no communication at all.
- Despite individual efforts to make the team successful, meetings focused heavily on complaint resolution.
- Other students do not support an individual's opinions and dismiss them.
- Students reminded to be quiet by other students while working with the industry partner.
- Teams had issues with students providing feedback on the project.
- Students fight for a leadership position on the team and talk over each other in meetings.
- Lack of input from teammates on each other's performance hinders improvement and makes moving forward difficult.

Grading

- Single student's share they did most of the work and should be recognized for that effort.
- Students accused others of copying from them.
- Faculty mentor is grading differently from other faculty mentors – example given was a D was given when their project was clearly better than another that got a B.

Personal Issues

- Personal emotional issues of student affect the team.
- One member tries to make up for their shortcomings by bringing the team baked goods.
- Student felt as if they were an unwanted member of the group.
- While students felt that an international group would lead to an interesting experience, the international students were not contributing as much to the project as the domestic students.

Industrial Partner

- Industrial partner changes scope of work and initial budget, creating difficulty for the team.
- Industrial partner defined the project in detail and then dismissed their direction in favor of a more ambiguous project description.

Faculty Mentor

- Faculty mentors were concerned about the capabilities of the students.
- Students were concerned about the faculty mentor as they only wanted to "chit chat."

Miscellaneous

- The project is "terribly vague."
- Student becomes defensive of scores previously given in CATME.

While the following positive situations were identified:

- Teams identified industrial partner and team as good to work with.
- Teams indicated that things were going well.
- Team members agreed that they had issues with motivation, but once they started their work was of high quality and exceeded expectations.

More of the comments indicated positive situations. These groups made statements like: "Keep It Up!," "Love Working With This Team," and "I'm proud of the team and the work we accomplished.

What Else Was Learned Using CATME

The data presented here is for the fall semester course. There are 38 different project teams, sponsored by 25 different companies, several companies are sponsoring multiple projects. In the fall semester of 2016, 147 undergraduate technology students enrolled and completed the first Capstone course. The brake down by major is as follows:

- Mechanical Engineering Technology (MET) 68
- Electrical and Computer Engineering Technology (ECET) 79

Most of the projects that companies are providing require MET and ECET skills. Of the 38 projects that are being done by the students, 25 teams have MET and ECET members. A stage/gate process is used to move the student teams from project proposal, conceptual design, preliminary design, critical design review, fabrication and test, and to final deliverable.

In the fall semester, the following three gates occurred, they are, project proposal, conceptual design, and preliminary design. Each gate requires the team to do a presentation and written report. In addition, each team member is required to submit their personal project notebook for scoring [5] and to complete a peer evaluation of their team members using CATME. Each gate, in the fall Capstone course, occurs approximately every 5 weeks. Therefore, the CATME results are available for review at three points in the semester and can be used as in course assessment.

In addition to student comments, CATME [20] provides two additional sources of information that can be used to assess team and individual performance during the course. They are:

Performance Measures: Students Rate Each Other

- C - Contributing to the Team's Work
- I - Interacting with Teammates
- K - Keeping the Team on Track
- E - Expecting Quality
- H - Having Related Knowledge, Skills, and Abilities

Satisfaction Measures: Students Measure the Team NOT Each Student

- 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

For the first gate, it was determined that the satisfaction measures, the students measuring the team and not each other, was the best indicator of team performance. The student responses were more honest because the students were evaluating the terms "teammates" and "team" not individuals. However, by the second gate, the performance measures were more in line with the satisfaction measures ratings. Also by the second gate, the student's comments had moved to being more specific and descriptive statements about the team and individuals.

In all, 24 students were identified by the Satisfaction Measures as measured by a scale of 1 to 4, with 4 being the highest. If any response to a Satisfaction Measures, at gate 1 or 2, were less than 4, the course instructor would make a point to stop by more often and visit with the team during the lab times. If by gate 2, the Satisfaction Measures were still going down a formal meeting with the team would take place to talk about the issue. These interactions continued throughout the course. The outcomes of these interactions are as follows:

- The satisfaction measures of 16 students improved by gate 3
- The satisfaction measures of 6 students did not change by gate 3
- The satisfaction measures of 6 students went down by gate 3

In addition, the satisfaction measures for 6 other students went down from gate 2 to gate 3. The CATME data from gate 1 and 2 for these students was very good and gave no indication of any issues. These students were never targeted for any extra interactions based on their CATME data.

Discussion

Overall, it appears that students in this particular Capstone course found the experience satisfactory. Some students found conflicting courses and assignments more important than working on the project assigned in the Capstone course; they made excuses and did not participate in the assigned course activities. In that case, students that do not participate are not gaining valuable teamwork skills. However, it is arguable that the balance of the team is learning how to deal with evasion, procrastination, and lack of motivation. Linhof and Settle [9] suggest that the use of regular presentation of their work will continually motivate students. The university that provided the data uses six evaluation periods over a two-semester course. These

periods involve presentations, documents, and poster sessions designed to maintain the student's interest. While this works for some, it becomes a hindrance for others. Given the positive nature of others findings, there is evidence to support continuance of this practice.

Considering the feedback from the Capstone course, clear lines of communication are essential to the success of the team building project [21]. The evidence supports that students realize communication is important, based on the comments many do not know how to communicate within their teams. The means of communication may include spoken , written [22], and general skills required for lifelong interaction [23]. Students that have not achieved confidence in these skills have issues navigating the workplace. Investigation on how to support the learning of these skills before taking the Capstone courses is essential to these students as they graduate and move into careers, employers expect it [24-26].

Industry partners and faculty mentors are essential to the successful team building experience. Industry partners model the working experience [27],while faculty mentors guide students through academic requirements and successful completion of the project[28]. Students rely on professionals in both industry and academia to guide them through their first project requiring the consolidation of all they have learned while in school. If they are not available, present, or supportive, students feel abandoned and confused as noted by the data provided by students in the CATME data provided to the researchers. Further training[29],sharing expectations with professionals in industry and academia is critical to the success of students in Capstone courses.

Considering the data provided by the survey and the CATME data analysis, three recommendations become evident for ways to influence the teamwork skills of engineering technology students.

- Continue use of the six evaluation periods to motivate the students and suggest that those participating institutions implement this practice if they have not already.
- Communication skill development is important in the successful interaction of team members and a good experience in the Capstone course. Further integrating instruction in various types of communication skills into the engineering technology program to prepare students for their careers, is critical to their success in the capstone course and their transition into their career later.
- Finally, training that includes strategies for successful mentoring and requirements to guide teams through their Capstone experience are necessary.

Considering the data provided it is evident that support from both the professional and academic mentor is essential for a positive Capstone experience.

Conclusion

This paper represents a first step in what is to become a multi –institutional initiative focused on identifying best practices for developing and improving teamwork skills within the Capstone experiences of engineering, technology and computing programs. The collaborators represent a diverse set of Technology Capstone course designs and philosophies. We expect the annual workshops and use of the CATME training and peer evaluation tools and the measurement of

behavioral complexity to lead to new research collaborations and new research directions, for example including: 1) what is the change in teamwork skills across the entire Technology matriculation-freshman to senior?, 2) what other courses in a Technology program have or should have a significant impact on teamwork skills?, 3) what impact do external experiences like internships or COOP programs have on the teamwork skills of Technology students?

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