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Student-Centered Assessment of the Capstone Design Project Course in Mechanical Engineering Program*

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This paper focused on how a competent faculty member could improve the learning experience and reduce the anxiety of the students of the capstone design projects in the mechanical engineering program. The faculty advisor provides the students with the guidelines of the best engineering practices and frequent feedback throughout the project. Two main changes have been implemented and tested in managing the capstone design project course in the mechanical engineering program. First, the course requirements have been divided into multiple deliverables that were distributed throughout the semesters instead of having all the requirements delivered at the end of the semester. The overall grade was distributed among these deliverables instead of having only a final report and a presentation. Second, for each deliverable, a customized rubric which detailed the expectations of the project sponsor and the faculty advisor, was provided to the students. Such rubrics act as a roadmap for the students so that they can accomplish the project goals with minimum day-to-day help from the faculty advisor. Additionally, rubrics for the soft skills, such as teamwork effectiveness and time and communication skills were provided as well, so that students were aware of what were expected from them. Mixed qualitative and quantitative approaches have been used in this study including, questionnaires, surveys, course evaluations, and observations. The new changes proved to be effective in improving students' learning experience, reducing the students' anxiety, and improving the assessment objectivity and transparency as well. However, the effect of using rubrics to assess the soft skills was not measured separately.

Keywords: mechanical engineering capstone design projects; self–learning assessment rubrics; assessment of students' soft skills; students' anxiety

1. Introduction

The capstone design project course which is considered a problem-based learning (PBL) course has multi-faceted importance. It provides a venue for the students to apply and integrate the acquired knowledge throughout their college experience in solving ''real world'' problems with some independence and flexibility. Moreover, the capstone design project course is mandatory for graduation for most US engineering schools. Such a type of problem-based learning (PBL) course is required by the Accreditation Board for Engineering and Technology (ABET) in the United States [1]. Furthermore, employers are interested in how successful students can use the gained knowledge in solving real-world problems [2], and they usually sponsor a good percentage of these engineering projects.

A successful capstone project course should satisfy the minimum requirements for useful knowledge which is defined as ''knowledge that comes from information combined with experience, context, interpretation, and reflection'' [3]. Faculty advisor has a challenging task to leave such a high impact on the students over a short period and assess their performance.

Indeed, the ideal role of the faculty advisor is a facilitator or a mentor [4]. Therefore, the faculty advisor must be capable of playing such a crucial role. Previous research in skill development [5] stated that ''students mature most readily'' when a pedagogy combined both challenge and support. During the capstone experience, students demonstrate the ability of self-learning about topics that were not covered through the college years. Often, in response to project complexity and challenges and in an attempt to meet scheduled milestones, students tend to be more dependent on the faculty advisor. Faculty provide the students with the needed resources and resist to play neither the instructor role nor the problem-solver role. These resources might include technical handbooks, technical manuals, research papers, or trustworthy online references. It is noted, based on the authors' experience that early intervention and guidance from the faculty advisor greatly assisted the team to get back on track.

A considerable amount of research has focused on different aspects that contributed to the success of the capstone design course offered in different disciplines from the industry sponsors' perspective, faculty perspective, ABET, and Educational requirements. However, little research has been done on the students' perception of the capstone design project and anxiety that students might have.

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Orsmond et al. [6] discussed the role of the advisor in enhancing the skill development of the students. They surveyed both students' and advisors' perceptions about what skills have been developed or reinforced during the project work. The survey results showed a discrepancy between students' perceptions and faculty advisor's perception. Therefore, in such a student-centered learning environment, students and faculty agree on the same roadmap to complete the project successfully.

Ambiguity and uncertainty associated with the capstone design projects at Aeronautical Engineering Technology (AET) program at Purdue University were highlighted by Dubikovsky [1] as the major students' concerns. Therefore, devising a unified method of managing the capstone design project course that is clear enough to convey the faculty and sponsor's expectations and reduces the students' anxiety, is needed. Also, this method would meet the pedagogical requirements by ABET, and the professional skills required by future employers.

The biggest challenge the students might have is that they did not know how they would be assessed and what was expected from them. Assessment rubrics might be utilized to communicate these requirements and expectations.

Assessment rubrics are a common practice in the capstone design project courses in engineering and non- engineering disciplines. Most of the assessment rubrics in literature were designed to satisfy the ABET requirement of continuous improvement [7, 8]. For example, Jones and Tadros [9] developed an end-of-year assessment rubric to assess student learning in the mechanical engineering program. The rubric's ten attributes were related to the ABET program learning outcomes, and it was shared with students at the beginning of the semester to raise their awareness of the expectations. However, this rubric did not provide enough details or guidelines to the students of what they should include under each attribute. Furthermore, the students were not provided with feedback on what they have achieved since this assessment rubric was used at the end of the semester. But the author rectified that by having a mid-semester oral presentation and used a simple binary rubric (0 – unsuccessful, 1 – successful) to assess the student performance. Yet, there was no clear connection between its attributes and the end-of-the-year rubric's attributes.

Gnanaparagasma and Canney [10] developed and used rubrics in the civil engineering industry-sponsored capstone projects that extend for year-long in the Seattle University. Their objective was to regulate the grade schemes across faculty advisors taking into consideration the project difficulty, multiple reviewers using these rubrics, and the diversity of the project types. Their capstone design project had two main deliverables: a proposal and a final report. To achieve their goals, the proposed rubrics for the proposal and the final report were similar and very detailed so that the reviewers' preferences would be eliminated. The rubrics included 11 to 12 criteria on a 6-point scale each. However, for usability purposes, the authors chose not to give a detailed definition for each level of each criterion. For each criterion, the characteristics for level 6, which was very strong and level 1, which was very weak, were defined and the intermediate scores were left for the reviewers to interpolate.

The proposed rubrics had enough details for the students to learn what expected from them, but they lacked the detailed criteria for the technical contents, and it was up to the reviewers to decide. Additionally, the proposed scale ranged from 1 to 6 with the only two extremes being fully defined, it was quite a wide range that might lead to students' speculations and increased their anxiety. Another concern regarding their overall assessment system was that the overall grade was based only on two written deliverables at the end of the year when the senior students usually are overwhelmed with other courses and their graduation.

Using rubrics in the capstone design course is also a common practice in the non-engineering disciplines. Levia and Quiring have created an analytical formative assessment rubric in their capstone design course in geography. They highlighted the benefits of using explicit rubrics in problem-based learning courses [11]. Gerhardt and Weld utilized the rubrics in a capstone design course for the mathematics discipline that synthesized the knowledge acquired in the major, increased the student confidence, and created foundations for lifelong learning in mathematics. In this course, students were asked to teach their peers and the faculty about a mathematical concept with a case study. An assessment rubric was used to assess mathematical correctness, presentation skills, and student's confidence [12].

In our capstone design project course, some inconsistency was observed that might contribute to the students' anxiety. The assessment scheme used in our capstone design project course varied based on the faculty advisors. There was also some inconsistency in the type of criteria and degree of evaluation of certain outcomes. Some discontinuity has been observed for some criteria evaluation due to the fact that different faculty being assigned to the capstone teams. In addition, the rubrics were communicated to the students in different formats with varying levels of details based on the faculty and most of the time the assessment occurred at the end of the semester. Moreover, the soft skills, such as teamwork effectiveness and leadership skills were

not emphasized enough and were not assessed separately. Additionally, students were not aware of how such soft skills would be evaluated.

In this study, the authors investigated the impact of using a new student-centered assessment rubrics that were not only used for technical guidance and assessment but also guidance and assessment of best practices and soft skills. Furthermore, multiple deliverables were distributed throughout the semester instead of having one final deliverable at the end of the semester so that the overall grade was divided among these deliverables. Each deliverable had its own detailed assessment rubric. Authors assumed that the new approach would contribute to the improvement of the students' learning experience, as they received multiple feedback, making them less anxious, and more equipped for the professional work environment.

2. Methodology

Mixed quantitative and qualitative approaches were employed in this study. This included end-of-project surveys, mid-term and end-of-term questionnaires, observations and course evaluations. All of the students' responses were anonymous.

At the beginning of the study, the role of faculty who mentored capstone projects was evaluated through surveys that were distributed to the prior students. 45 students responded to the survey. Students were asked if "faculty advisor played a significant role in the success of the capstone project." The results presented in Fig. 1 showed that around 60% of the students either strongly agreed or agreed that the faculty advisor contributed to the success of their projects. 30 % of the students were neutral, and 10% disagreed.

Having this feedback from the students, it was decided that the advisor role should be more streamlined and well defined. All faculty involved in capstone projects would share a similar approach/methodology and the same assessment scheme.

The ME Program has a yearly average of 80 senior students divided into 25 to 30 teams that are engaged in the capstone design project courses during their senior year. Each faculty is assigned a 3-credit from his/her teaching load when advising 6 teams. The faculty are selected based on their expertise. However, this may vary slightly based on the nature of the project, the number of students per team, and the faculty teaching load. Students select their own projects and choose their team members, but their faculty advisor is assigned to them. The typical team consists of three to four students. The majority of the projects are industry-sponsored while other project ideas are initiated by the students and stem from the students' interests, and some project ideas are suggested by faculty. In all cases, the faculty advisors must approve the project idea and scope.

The capstone project courses extend over two semesters and split over two courses. During the first course, the students learn about the best practices in engineering design & product development cycle, engineering economy, project management, and professional conduct which include ethics, laws, and regulations. Recently, the team effectiveness strategies were added to the course modules. Based on authors' experiences in industry and academia, the authors summarized the technical and soft skills in Fig. 2. and shared it with other faculty and students. These skills need to be reinforced and assessed during the two-semester capstone design courses. The technical skills focus on

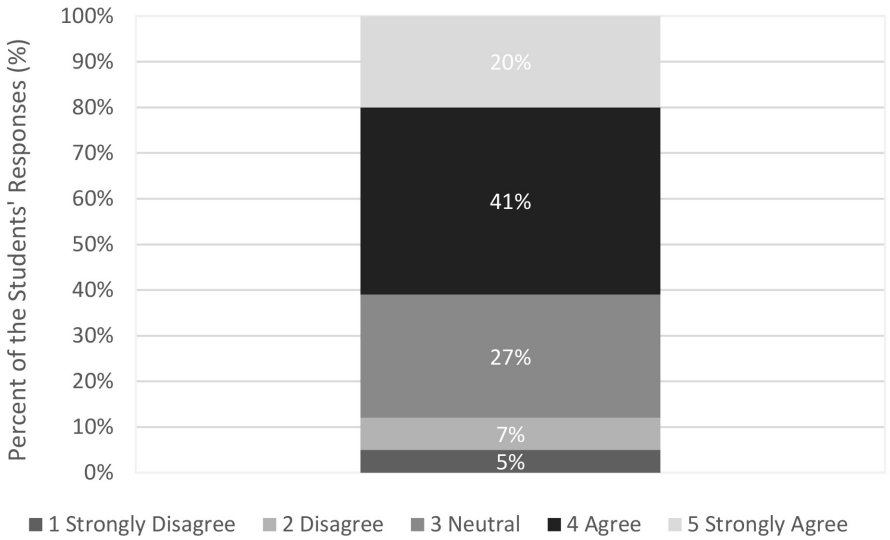

Fig. 1. Students Responses to a Faculty Role Survey.

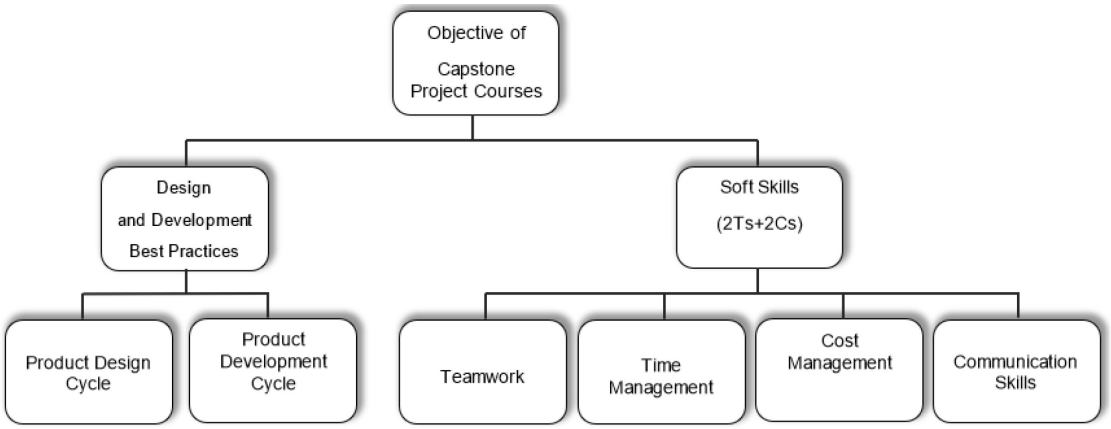

Fig. 2. Technical Skills and Soft Skills that need be Reinforced in the Capstone Courses.

the product design and product development cycle as illustrated by the product development process best practices shown in Fig 3. This figure was modified by the authors from the original Dym's model [13] to emphasize the design phase of the product development process. In many capstone projects, the validation of the prototype for production is not implemented as it would be in a typical industrial manufacturing set-up. During the second course, the students are required to transfer the concept idea that developed in the first capstone course into an artifact as defined by the modified Dym's model.

Throughout the two courses, students develop and reinforce their soft skills (2Ts+ 2Cs) as referred to in Fig. 2. The 2Ts stand for the teamwork and time management while the 2Cs stand for the cost management and communication skills. Many studies highlighted the importance of soft skills and sometimes they are called professional skills in preparing the students the workforce [14, 15]. Working in teams effectively, fulfilling the time frame for the project milestones, managing the project cost centers, and communicating effectively are the major soft skills that need to be improved and frequently assessed by the faculty advisor.

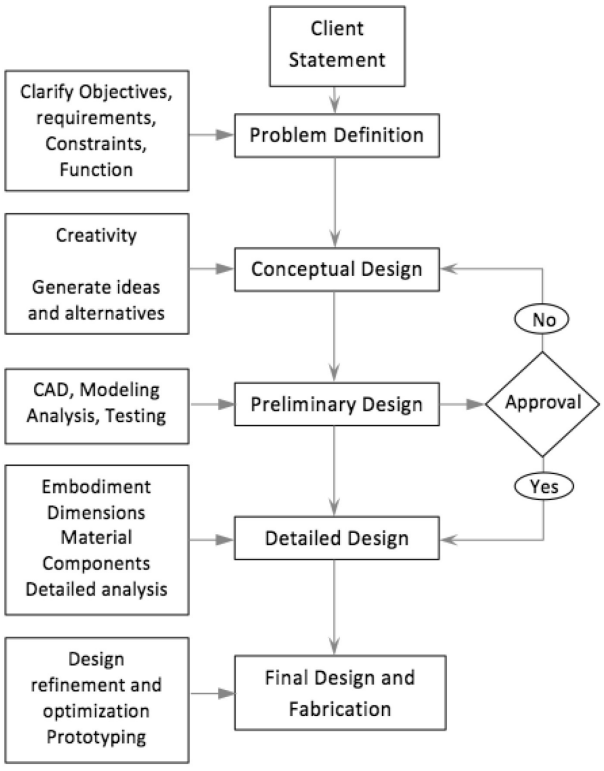

Fig. 3. Product Development Cycle-Modified Dym's Cycle [13].

Some guidelines were agreed upon in our capstone design course faculty meetings. The faculty advisor provides guidance early during the project selection stage. The faculty is aware of the students' learning goals and career goals. This would enable the faculty to suggest projects that match their goals. This can be done through open discussions with the students or tailored questionnaires based on the projects' pool.

A faculty advisor communicates with the students what skills to be developed, or reinforced, why these skills are important, and how these skills will be assessed. These will reduce the roadblocks and anxiety during the course.

More importantly, a faculty advisor elucidated to the students how they would be assessed. The timeline of the project milestones and deliverables and their grade percentages were clearly stated. It was agreed to distribute the project deliverables throughout the semester instead of having one final assessment at the end of the semester.

For each deliverable, the faculty agreed on the unified and detailed rubric that addressed the capstone project learning outcomes. The rubrics were designed in such a way to be self-explanatory to enable the students to be self-learners and help them to accomplish the project deliverables independently. The initial rubrics were continuously improved and refined based on the feedback from the students and faculty advisors. These rubrics were shared with all groups of students at the beginning of the capstone project course. Also, the faculty gives constructive feedback for each deliverable or/and milestone, so that the students could learn their weaknesses and work on improving them.

This approach was expected to be effective in enhancing the students' learning experience and reducing their anxiety regarding the grades. Also, it would increase the sense of self-confidence and self-accomplishment for the students. Finally, it would promote the students to focus not only on the grades but also on the approach, so they would learn the best practices in accomplishing their project deliverables.

Table 1 presents the timeline for the project milestones that were shared with the students in both courses. These were included in the course syllabus and thoroughly discussed during the first day of classes. The deliverables are distributed throughout the semester. Each deliverable is designed to reinforce one or more of the technical or soft skills as shown in Table 2. The faculty advisor shares with the students a detailed assessment rubric for each deliverable so that students know the expectations ahead. An example of a detailed rubric for deliverable "demonstration 1" is shown in Table 3.

The students' surveys were sent electronically to 132 students to seek their feedback on the effectiveness of the newly implemented assessment rubrics

Table 1. Capstone Project Milestones for course I and course II

Project Milestone for Course I	Week Number	Project Milestone for Course II	Week Number
Meet and Greet with Faculty Advisor and Sharing the Syllabus	Week1	Meet and Greet with Faculty Advisor and Sharing the Syllabus	Week 1
Project Selection	Week 6	Detailed Actions Plan	Week 4
(a) Identify the target market or customers and their primary needs. (b) Research similar products on the market. (c) Identify certain gaps (needs) to be fulfilled.	Week 8	Demonstration 1	Week 7
(a) Develop different concept designs, which include a description of the form, function, and features.	Week 12	Bill of Materials Approval and Components Purchase	Week 8
(a) Select the best concept design and compare it to customer needs. (b) Estimate the overall cost and Gantt Chart.	Week 14	Demonstration 2	Week 13
(a) Project proposal report submission.	Week 15	Final Report Draft + Conference Presentation Draft	Week 15
Proposal presentation	Week 16	Conference Day (Final Demonstration) + Final Project Report	Week 16

Table 2. Grades Distribution throughout the Semester

Skill/ Deliverable	% Grade
Teamwork Effectiveness and Peer Assessment	10%
Project Management (Leadership): Time, Cost, and Communication	20%
Technical Skill (the product meets the Customer Requirements and Constraints)	10%
Midterm Demonstrations	20%
Weekly Meetings with Advisors	5%
Final Report	20%
Final Presentation	15%

on their learning experience, anxiety level, and fairness of the grades they were received at the end of the year and after their grades were posted. Furthermore, it was emphasized that their feedback would be anonymous.

Before implementing the new assessment, the majority of faculty advisors overlooked the importance of assessing soft skills separately. Faculty had a tendency to tie the assessment of the soft skills to the performance of the technical skills.

Both faculty advisors and students might find difficulty in evaluating teamwork effectiveness and leadership skills. To address this challenge, the authors were interested to know the students' opinions of teamwork and why they might be interested in teamwork. So, 45 junior students were asked an open-ended question if they preferred the group work over the individual work or not and why.

3. Results

Different tools, such as the end-of-the-semester surveys and the course evaluation forms were used to assess the effectiveness of the new approach of managing the capstone project course from the students' perspectives.

3.1 Students' Learning Experience and Anxiety

The students' feedback on the effectiveness of the new assessment rubrics on their self-learning experience is illustrated in Fig. 4. More than 70% agreed on the usefulness of the newly designed assessment system. Only 11 % considered these new rubrics not useful. In Fig.5, 65% of the students agreed that the self-learning rubrics reduced their anxiety throughout the capstone design courses.

3.2 Fairness of the New Assessment System

The course evaluation was another tool used to measure the effectiveness of the new assessment system. One question in the course evaluation inquiries about the fairness of the overall assessment system of the course. The students' responses to the old assessment system are shown in Fig. 6 whereas Fig. 7 shows the students' responses to the new assessment system, which used self- learning rub-

Table 3. Example of Rubric for Demonstration 1 in Week#7 of 2nd Capstone Design Course

Item	Excellent	Acceptable	Poor
Motivation & Problem Statement	1. Motivation. 2. A problem well-defined. 3. Selection Criteria & Design Specifications are highlighted.	1. Motivation is not clear. 2. The problem is not well stated. 3. Missing some of the design specifications.	1. Motivation is missing or, 2. Problem Statement is missing or, 3. The design specifications missing.
Description of the System	Description of your product includes: 1. Hand sketching of concept design. 2. 2D & 3D CAD models, including detailed drawings with the dimensions. 3. The System decomposition into subsystems and components. 4. Design Testing. 5. Meeting the Specifications.	1. The system not fully described. 2. Testing Plan is not thorough. 3. Some Drawings are missing.	1. The description of the system is not clear. 2. Missing drawings. 3. Major tests missing. 4. Missing system components.
Applied Engineering Principles	1. Underlying theories and concepts are highlighted. 2. Detailed calculations are done.	1. Some concepts are missing. 2. Minor mistakes in calculations.	1. Missing major concepts or principals. 2. Major mistakes in calculations.
Sub-System Prototype	1. Show evidence of the progress in component or subsystem prototyping. 2. A complete plan for all prototyping of all components.	1. Little evidence for the progress in components prototyping. 2. Incomplete plan for the components prototyping.	1. No evidence for the component prototyping. 2. Missing the prototyping plan.

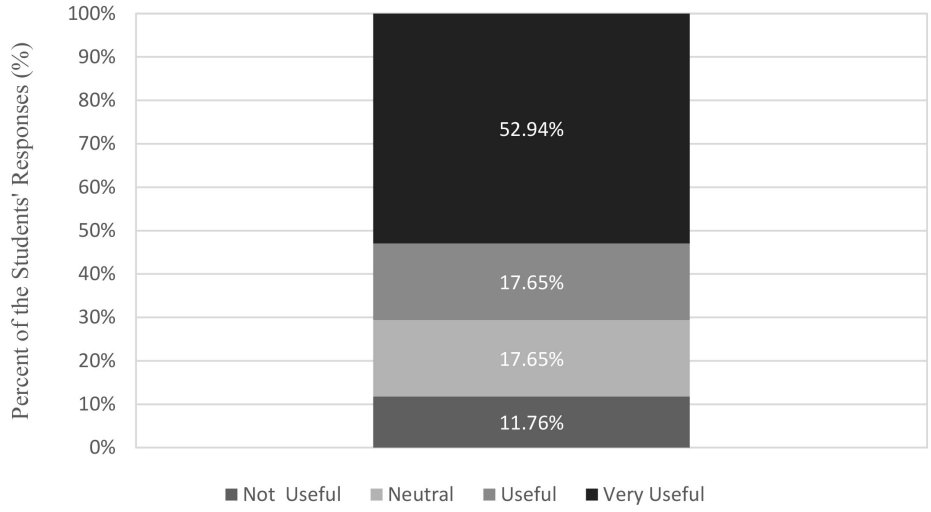

Fig. 4. Students' Feedback on the Effectiveness of the New Self –Learning Rubrics.

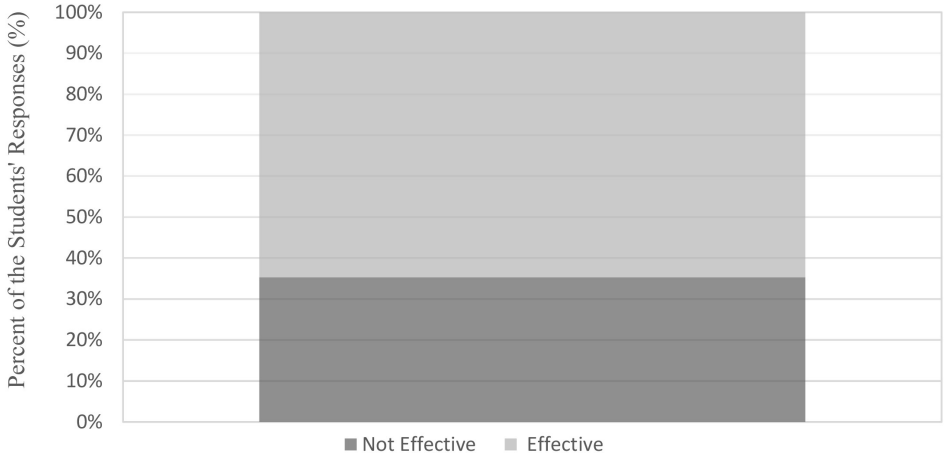

Fig. 5. Students' Feedback on the Effectiveness of the New Rubrics in Reducing Anxiety.

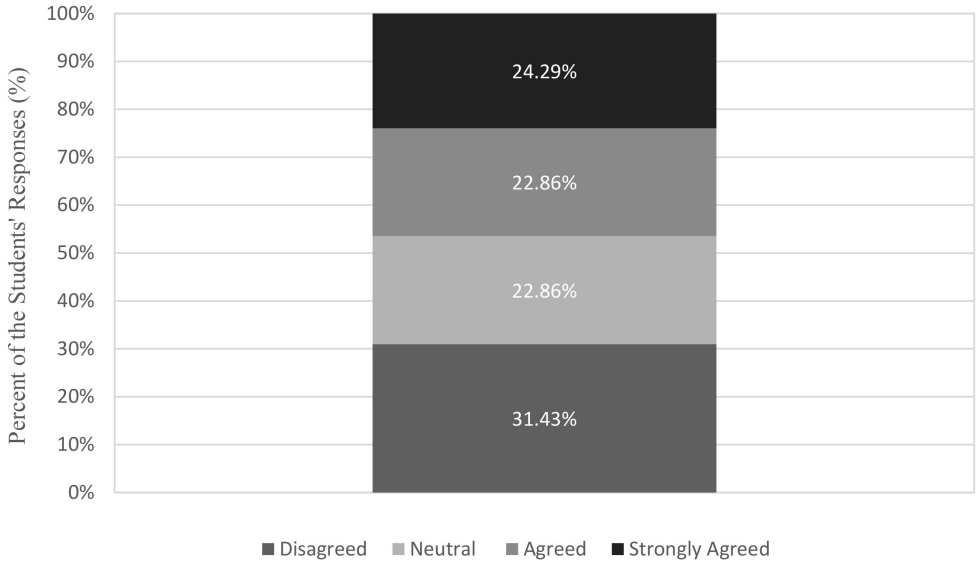

Fig. 6. Students' Feedback on the Fairness of the Old Assessment System.

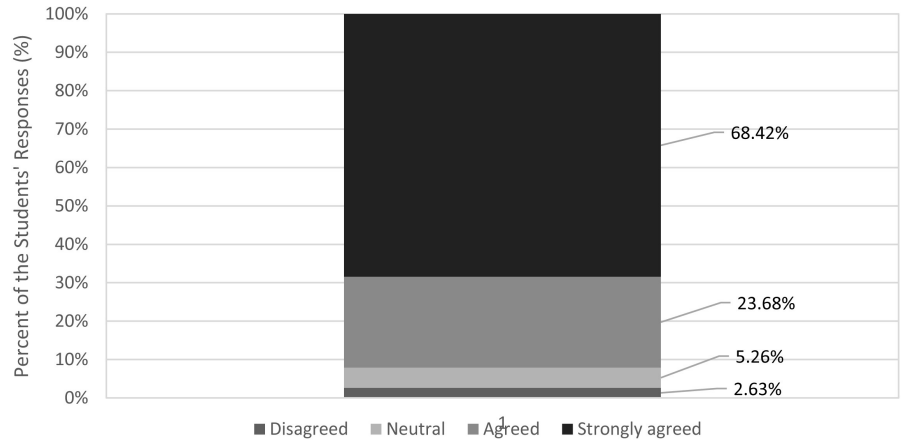

Fig. 7. Students' Feedback on the Fairness of the New Assessment System.

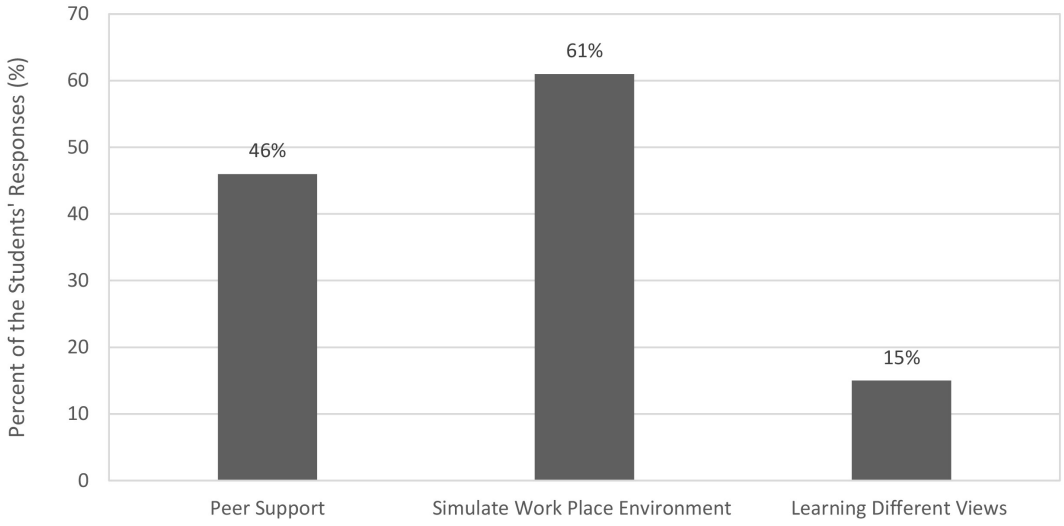

Fig. 8. Reasons Why Students Prefer Teamwork.

rics. Over 92% of the students agreed that the new assessment system was fair versus only 42% of the students agreed that the old assessment system was fair.

3.3 Assessment of Soft Skills

The responses of 45 junior students about teamwork were illustrated in Fig. 8. All students preferred group projects for different reasons. More than 60% of the students responded that group projects mimic their future work environment and this type, of course, gives them the opportunity to practice how to work effectively in teams. Whereas 46% of students noted that they preferred the group work because of peer support, only 15% stated that they wanted to have different perspectives on the problem analysis and solution. The survey outcomes indicated the students' awareness and appreciation of the significance of teamwork effectiveness. However, it could be anticipated that 46 % who sought peer support might negatively rely on their team members and not being effective team members. This agreed with the findings of [16] that stated 35 % of the students reported a major concern regarding the mismatch of the members' efforts and most of the team conflicts stemmed from the unequal workload. Some students, towards the end of the semester, feel overwhelmed with such an unfair workload; therefore, conflicts may arise. Faculty anticipated that if the following two activities were implemented, the team effectiveness would be improved, and the soft skills could be assessed objectively. First, the workload was agreed upon at an early stage of the project. Second, the faculty advisor monitored the performance of each member during the weekly follow- up meetings. The authors suggested some guidelines to put these two precautions in action. At the beginning of the course, each team member was required to share his/her strengths and weaknesses regarding the topics, such as the familiarity of the required software tools, and the hands-on expertise related to the

project. Then, the total number of tasks and the required man-hours were calculated and divided among the team members based on their skill set. Finally, the action plan was generated and shared with the faculty advisor to make sure that the workload, difficulty level, and genuine contribution were equally distributed among the team members. During the weekly meetings, the faculty advisor reviewed the actions plan to make sure that the team follows the proposed project timeline and assessed the performance of the team members. Additionally, they recommended to add a peer-review to the course overall assessment and asked the team members to use a standard rubric provided by the faculty advisors to evaluate their peers' performance. This rubric was designed based on the team skills rubric by Borrego et al. [17] who did a comprehensive review of how to assess and improve team effectiveness in engineering education and specifically capstone design courses. Three aspects were assessed in the peer-review evaluation: quality of output, on-time task fulfillment, and value other's viewpoint.

After implementing these strategies, the authors observed that the teams that had no conflict scored ''excellent grades''. The teams that had conflicts but managed to resolve them at the early stage, they scored ''very good ''to ''good grades''. Yet, the teams who had conflicts that could not be resolved, they could not finish their project deliverables and they scored poor grades. Another strategy the authors implemented to improve and asses the soft skills was to assign a team lead to be responsible for time management, cost, and communication.

A separate survey was distributed to 50 students at the end of the second semester to know the students' feedback on the importance of the team leader role to the project success. Fig. 9 shows the outcomes of this survey. The results pertained to the insignificant role of the team lead from the students' perspective. This prompted the authors to pay more attention to define and follow up on the responsibilities of the team lead as managing the cost and time schedule of the project, acting as a liaison between the faculty advisor, the project sponsor (customer) and the team members, and keeping the meeting's logs. Furthermore, it was anticipated to be more beneficial to circulate the project lead role among the team members so that each team member has the opportunity to develop this skill and the faculty could assess this skill individually.

4. Discussion

Some changes were suggested to manage the ME capstone design project courses more effectively while alleviating the students' anxiety. Two major changes were implemented by all faculty advisors: (1) each faculty provided a detailed rubric for each deliverable that explained the expectations including the soft skills, such as time management and teamwork effectiveness, (2) the overall grade of each course was divided over multiple deliverables throughout the semester. The results in Fig. 4 and Fig. 5 indicated that the new assessment strategy was effective and helpful in reducing students 'anxiety to more than 50% of the students. The students also found the detailed rubrics very useful in communicating the expectations of the project sponsors and the faculty advisor. Furthermore, the students used these rubrics as a roadmap to accomplish the project deliverables. Assigning multiple deliverables throughout the course might result in many benefits to the students. First, the students receive multiple feedback from the advisors and sponsors throughout the semester which would help them to improve and refine their designs. Second, the anxiety associated with one final grade at the end of the project

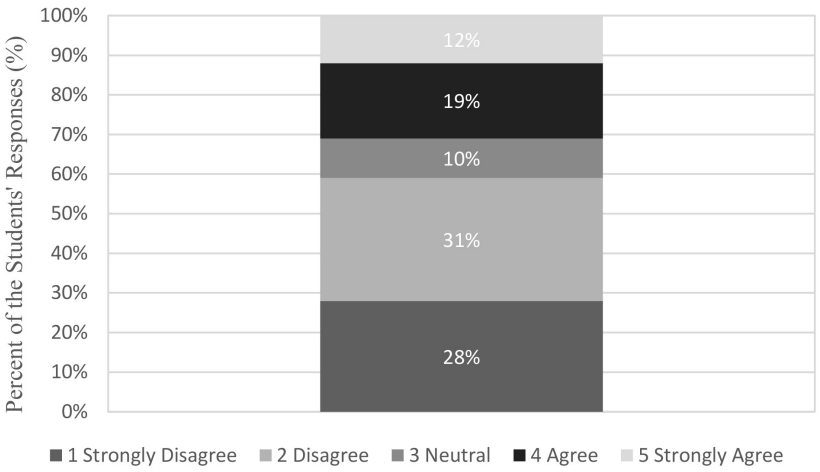

Fig. 9. Students 'Perception of the Role of the Team Lead.

would be reduced. Instead, the students would earn their grades as they progressed in their project and they would become more confident towards the end. Only 35% of the total grade was assigned to the final assignments. Finally, the project workload is distributed throughout the academic year and students do not need to jam everything towards the end of each course as they used to do.

In the new assessment method, the soft skills, such as teamwork effectiveness and leadership were assessed separately throughout the semester and contributed to 30% of the total grade. This approach was expected to encourage the students to focus more on the process not only on the final results, to follow the best practices, and to work on improving their soft skills which are crucial to their success in their professional careers.

Having many faculty involved in advising the capstone design project course, it was essential to know the students' perception of the grades they received whether it was just or not. As it was illustrated in Figs. 6 and 7, 92% of students to whom the new assessment system was applied reported that they received a fair grade comparing to only 42% of students of the old system. This might be due to the transparency of the assessment method which shared early with the students, the multiple assignments and the frequent feedback the students received from their advisors for each assignment. And most importantly, the unified assessment that every faculty had to follow compared to the old assessment system which was up to the faculty advisor to decide his/ her assessment schemes for their groups.

The difficulty in assessing the soft skills assumed to be stemmed from ill-defined responsibilities and roles of the team members. So, the focus was to define the roles and responsibilities of each member early in the project and a follow- up of the performance throughout the semester was performed.

4.1 Limitations and Future Study

Although implementing the new assessment strategy of the soft skills helped the faculty advisors to objectively and fairly assess the students, the authors did not quantitatively track the effect of the new strategy on the improvement of team effectiveness and leadership skills. The might be addressed in a future study. Furthermore, the authors suggested adding the team conflict resolution strategies to the syllabus of the first course of the capstone design projects to better prepare the students to avoid or resolve conflict in later stages of the project. However, the impact of this module addition was not investigated yet.

Implementing the new assessment strategy proved to be effective in reducing the student's anxiety and improving their learning experience. One limitation of this new strategy is the more time required from faculty. The faculty needed to develop multiple rubrics for the different deliverables for at least six projects, to grade multiple project deliverables, to provide multiple feedback to each group member, and to follow- up on the soft and technical skills as well. One suggestion to address these challenges is to reduce the number of projects assigned to each faculty and to increase the number of faculty who teach this course. Another suggestion is to group the projects by the scope and assign each group to a certain faculty so that the faculty needs to develop fewer rubrics and can meet with multiple groups at once to discuss the general technical requirements. A more long-term recommendation is to document all detailed rubrics which were developed by faculty and create a depository of rubrics from which the faculty in the future would select the best match and slightly edit it. The impact of this student-centered assessment strategy on the faculty time should be investigated.

5. Conclusion

The capstone design project course has unique pedagogical importance. It showcases the students' technical knowledge as well as their soft skills. Therefore, more effort is always needed to continuously improve the students' experience. In this study, the authors presented their experience to improve the capstone design project course in the mechanical engineering program. The goal was to reduce the students' anxiety and ambiguity while maintaining the pedagogical and industry sponsors requirements. Two key changes have been implemented to achieve this goal.

Dividing the course requirements into multiple deliverables throughout the semester and providing the students with a tailored rubric for each deliverable including the soft skills proved to be advantageous and realized the goal of the study which was reducing the students' anxiety. The students focused on one requirement at a time; however, they were aware of the big picture since all the requirements were communicated in the syllabus. Additionally, the students had the opportunity to receive multiple feedback from their advisors. Finally, the faculty had the opportunity to closely monitor, follow up, and objectively assess the students' soft skills, such as teamwork effectiveness and leadership.

The changes made to the capstone design project course have shown improvement in the students' response concerning anxiety, learning effectiveness, and fairness. However, the effort and time needed from the faculty advisors increased and should be addressed.

References

1. S. Dubikovsky, Senior Capstone Design Projects and Anxiety of Ambiguity and Uncertainty, *International Journal of Arts & Sciences*, **8**(6), pp. 193–198, 2015.
2. R. E. Schwering, Optimization Learning in Project-Based Capstone Courses, *Academy of Educational Leadership Journal*, **19,** pp. 90–104, 2015.
3. T. H. Davenport, D. W. De Long, M. C. Beers, Successful Knowledge Management Projects, *MIT Sloan Management Review*, **39**(2), 1998.
4. M. Omar, Design and Implementation of a Capstone Course to Satisfy the Industry Needs of Virtual Product Development and ABET Engineering Criteria, *Education Research International*, 578148, 18 pages, 2014.
5. T. A. Eppes, I.Milanovic, H.F.Sweitzer, Strengthening Capstone Skills in STEM Programs, *Innovation High Education*, **37**, pp. 3–10, 2012.
6. P. Orsmond, S. Merry and K. Reiling, Undergraduate project work: can directed tutor support enhance skills development?, *Assessment & Evaluation in Higher Education*, **29**(5), pp. 625–642, 2004.
7. A. Shaeiwitz, Mining Capstone Engineering Experiences for Program Assessment Results, *International Journal of Engineering Education*, **18**(2), pp. 193–198, 2002.
8. P. Vijayalakshmi, D. Desai and G. Joshi, Outcome-based education performance evaluation of capstone project using assessment rubrics and matrix, *2013 IEEE International Conference in MOOC, Innovation, and Technology in Education (MITE)*, Jaipur, pp. 6–10, 2013.
9. D. Jones and A. Tadros, Successful Use of Rubrics to Assess Student Performance in Capstone Projects, *2010 ASEE Annual Conference*, Louisville, Kentucky, June 2010.
10. [N. Gnanaparagasma and N. E. Canney, Work in Progress: Rubric Development for Year-long Civil Engineering Capstone Projects, *122nd ASEE Annual Conference &Exposition*, Seattle, WA, 27 pp., June 2015.
11. S. Levia and M. Quiring, Assessment of Student Learning in a Hybrid PBL Capstone Seminar, *Journal of Geography in Higher Education*, **32**(2), pp. 217–231, 2008.
12. I. Gerhardt and K. Weld, One Size can Fit all: A Problem-Solving Capstone Course, *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies*, **23**(4), pp. 326–346, 2013.
13. C. I. Dym and P. Little, *Engineering Design: A Project-Based Introduction*, 2nd ed., Wiley, New York, 2004.
14. D. Davis, M. Trevisan, H. Davis, R. Gerlick, J. McCormack, S. Beyerlein, P. Thompson, S. Howe, P. Leiffer, P. Brackin and J. Khan, Assessing Professional Skill Development in Capstone Design Courses, *International Journal of Engineering Education*, **27(**6), p. 4, 2010.
15. A. D. Lantada, J. D. Sevillano and A. H. Bayo, Promotion of Professional Skills in Engineering Education: Strategies and Challenges, *International Journal of Engineering Education*, **30**(6), pp. 1–14, 2014.
16. S. Hackman, J. Sokor and C. Zhou, An Effective Approach to Integrated Learning in Capstone Design, Informs Transaction on Education, **13**(2), pp. 68–82, 2013.
17. M. Borrego, J. Karlin, L.D. McNair and K. Beddoes, Team Effectiveness Theory from Industrial and Organizational Psychology Applied to Engineering Students Project Teams: A Research Review, *Journal of Engineering Education*, **102**(4), pp. 472–512, 2013.

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