A WEB-BASED ONLINE COLLABORATION TOOL FOR FORMULATING SENIOR DESIGN PROJECTS

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ABSTRACT

A well formed senior design project is known to have significant benefits in terms of project outcome, student motivation, team cohesiveness, engagement, and student learning. Defining a good problem statement, forming a team of compatible and appropriately skilled students, and selecting an appropriate faculty mentor are critical aspects of project formation. Therefore, students in Mechanical Engineering at Purdue University are encouraged to suggest project ideas, form teams, and have them approved by the course coordinator before the semester starts. While there is significant literature on senior design projects, most of the existing work is focused on activities after the problem is defined and the teams are formed. There is a lack of mechanisms and tools to guide the project formation phase in senior design projects, which makes it challenging for students and faculty to collaboratively develop and refine project ideas and to establish appropriate teams. To address this challenge, we have implemented an online collaboration tool to share, discuss and obtain feedback on project ideas, and to facilitate collaboration among students and faculty prior to the start of the semester. Through an online survey and questionnaire to students, we are exploring the impact of the collaboration tool on the senior design project formation process. In this paper we present the design of the tool and the results from our ongoing study in the senior design class at Purdue Mechanical Engineering.

Keywords: Online Collaboration, Senior Design, Mechanical Engineering

1 INTRODUCTION

Engineering design projects provide real-life design process experience to students [1]. Research shows that project formation process is one of the most challenging tasks associated with engineering design capstone courses [2]. The foremost task is framing good project definitions. Significant research has been conducted to understand the characteristics of a senior design project. According to Dutson et al. [3], a good quality project statement should:

- be challenging,
- simulate a real life problem,
- involve engineering design work,
- emphasize engineering theory and application, and
- meet specified standards and safety criteria.

Formulating a problem for a project is a challenge for both faculty and students. One of the main reasons is that an individual does not possess complete knowledge. As explained by Chandrasegaran et al. [4], it requires both formal and tacit knowledge to formulate a good problem statement. While the former type of knowledge is present in documents, repositories etc., the latter is only gained over a period of time with learning and experience. Thus, it is necessary to promote knowledge sharing activity among faculty and students.

Since design projects are team oriented projects, team formation is important. Different team formation processes are adopted by various faculty members to form engineering design teams. The most practiced schemes include [5]:

- letting the students self-select the team members,
• random assignment of team members by the instructors,
• team member selection based on prior performance, and
• group selection based on a heterogeneous mixture.

Regardless of the adopted scheme, individual team members’ motivation and enthusiasm about the project is one of the critical factors in the success of a project [6]. Instructors often conduct questionnaires about student interests, academic strengths and experiences in an attempt to form effective design teams [3]. However, there are generally groups of students whose individual interests do not align with the assigned project and hence, makes the process challenging.

Finally, selecting an appropriate faculty adviser is another important task in the project formation process [3]. Studies show that, for various reasons, faculty members are interested or motivated in mentoring only specific design projects [3]. Therefore, sometimes there are many projects and student teams but very few faculty members who are interested in advising them. Thus, there exists a need for a collaborative system where faculty and students can exchange ideas, form teams, select mentors and execute potential projects.

Over the past few years, several researchers have reported tools and systems to formulate projects and teams for successful project execution [6,7]. For instance, Wyard-Scott et al. [8] have implemented an online tool to foster communication among instructors and student team members. Similarly, Kanai [9] created a web-based bulletin board system to help faculty, students and industrial sponsors to stay connected. Lo et al. [10] have proposed an online collaboration system for senior design project grading and document review. However, these systems are focused on the activities after the problem is defined and the teams are formed. There is a lack of mechanisms and tools to guide the project formation phase, which makes it challenging for students and faculty to collaboratively develop and refine project ideas and to establish appropriate teams. The question that guided this study is: Does an online collaboration tool improve the project formation process in engineering design courses?

In this paper we present the design of an online collaboration tool and report the results of our ongoing exploration of the impact of this tool on senior design project formation process. The rest of the paper is organized as follows: the following section discusses the motivation followed by the design and implementation of the tool. We then present the evaluation of the tool. Finally, the results of an ongoing study and future work are discussed.

2 MOTIVATION

A senior design or capstone project is an essential part of many Mechanical Engineering programs. In the School of Mechanical Engineering at Purdue University, the Engineering Design course is offered to provide practical guidance to students in integrating various engineering sciences into practical engineering design projects. This allows students to apply and refine their design skills, teamwork skills and communication skills. Also, this course plays a vital role in assessing the ABET (Accreditation Board for Engineering and Technology) student learning outcomes [11].

In our engineering design course, a team of senior engineering students work on a design problem. Students, faculty and industry sponsors are the major sources of project definitions. The course coordinator has to ensure that the projects simulate a real-life project/problem and student team is motivated to solve the design problem. As a result, the students are advised to suggest project ideas, form teams and have them approved by the course coordinator before the course starts. The key activities that take place during this phase are:

1. problem definition and scoping,
2. team formation, and
3. faculty adviser selection.

During this phase, the course coordinator iterates with the student proposing the project to develop the problem statement until it meets the educational objectives of senior design. Then the students look for potential team mates, and the course coordinator looks for a faculty member to act as an adviser for the project in the coming semester. The entire process can be sub-categorized into three phases including the idea initialization phase, idea development phase, and idea finalization phase. Each phase has corresponding activities for carrying out the development to achieve a high quality problem definition and motivated student team. The key stakeholders in the process are the students, faculty, the instructor in charge and the industry sponsors. Figure 1 presents a bird’s eye view of activities and interactions among stakeholders during each phase of the process.

The lack of mechanisms and tools makes it difficult for the individual stakeholders to interact with each other. Current interaction methods such as face-to-face meetings and e-mail interactions are not effective for communication and successfully guiding a large number of students. Inadequate interactions among stakeholders at this stage result in problem definitions with poorly defined scope and incomplete capturing of requirements, thereby, significantly affecting the quality of problem definition. Other issues include:

1. Students often find it difficult to look for team mates who are enthusiastic and motivated about the specific project idea.
2. Students are limited by the number of faculty they can approach for guidance.
3. Good projects may be missed because the course coordinator is the single point of contact for the problem statement approval process.
4. At times, a faculty member can come up with a good senior design project which might take more than a semester
to complete. So, the faculty member might want to communicate this to the students and want to work with the team of interested students a little earlier.

Therefore, we hypothesize that implementing an online collaboration platform that enables participation and interaction among stakeholders will improve the project formation process. We also observe that creating a public collaboration platform will facilitate collaboration links that might otherwise not be made. The platform described here is intended for identifying high quality problem definitions and motivated student teams through increasing interactions among student and faculty.

3 ONLINE PLATFORM : REQUIREMENT ANALYSIS

In this section we present the critical requirements of the online platform. The requirements of the online platform are categorized into a) functional requirements and b) software requirements.

The functional requirements of the platform are as follows:

1. All stakeholders including students, faculty, and industry sponsors should be able to propose new project ideas.
2. The platform should allow all stakeholders to discuss and comment on the shared project ideas.
3. Students and faculty members should be able to register for interested projects.
4. The platform should allow students to communicate with each other and propose their own team.
5. Students should be able to archive their projects ideas in order to motivate students enrolled in future semesters.
6. The platform should allow the lead instructor to administer the project formation activity.

The software requirements of the system that are essential for choosing a system are:

1. The system should be able to provide access to all stakeholders.
2. The system should have password restricted accessibility and provide data security.
3. Currently, there are four different stakeholders in the system. The system should facilitate multiple user roles and permission levels.

In fact, knowing who the stakeholders should be and forming collaborative connections is a challenge. The use case diagram in Figure 2 illustrates the design details. As the diagram shows, the critical aspects of the system are collaboration, communication and information sharing among different actors.

4 IMPLEMENTATION

Existing learning management systems available at Purdue University, such as Blackboard/WebCT [12], do not satisfy several of the unique needs of the system. For instance, Blackboard limits accessibility to only students and faculty of a particular course and single section. As a result, students and faculty who belong to the same course but in a different section cannot collaborate through Blackboard. Additionally, industry
sponsors cannot have access to Blackboard. Also, other software requirements such as multiple user roles and permissions are not supported by Blackboard. Other available online platforms such as GlobalHub [13] which is developed using the HUBZero platform, is limited by the number of user roles available. Therefore, the online platform is implemented using Drupal, an open source web-based content management system [14]. Table 1 gives a comparison of existing online platforms and Drupal with the needs of the system.

The online platform is built on the LAMP [15] environment. The Drupal CMS is installed on top of apache web server. The complete platform architecture is illustrated in Figure 3(a). Drupal is built upon open source community contributed add-ons called modules. Each module is built to render a specific functionality to the web interface. In Drupal, each item of content is defined as a node and each node is defined as a specific content type. The platform is implemented by using modules and creating custom content types that meet the functionality of the system. The functional diagram mapping necessary modules [16][17] and content types to the requirements is illustrated in Figure 3(b). The detailed design and current implementation of the online platform is available at [18].

5 EVALUATION

Several researchers suggest that interaction is an essential element to student learning [19][20]. Hillman et al. [21] consider interactions among students, and between instructor and students.
as “educational transaction”. Research suggests that the amount of interactions is a performance measure of online platforms in academic setting [22]. To evaluate the effectiveness of the online platform we measured the amount of interactions among students and faculty both before and after the implementation of the online platform.

The study was conducted during Spring 2014 in which two groups of mechanical engineering senior design students were surveyed. The survey was administered in two phases. The first phase was carried out prior to the implementation of the online platform. During the first phase, a group of 194 Mechanical Engineering design students enrolled in the Engineering Design course were surveyed using the questionnaire presented in Table 2. This group of students relied on face-to-face meetings and email communication for formulating the engineering design projects i.e., forming teams and formulating problem statements.

During the second phase, the online platform was implemented and the students intending to take the course in Summer/Fall 2014 were encouraged to submit the project ideas and form teams through the online platform. This group consisted of 48 students. Students were informed about the online platform and were given a period of one month to frame the problem statements and form teams. After one month the second group of students was surveyed using the same questionnaire presented in Table 2. In comparison with the first group, the number of students were much lower in the second group because lesser number of students take senior design in the Summer/Fall semester compared to the Spring semester of an academic year in the school of Mechanical Engineering at Purdue University.

### Questionnaire

A questionnaire measuring the amount of interactions among students and faculty both before and after the implementation of the platform is conducted. The questionnaire addresses student-student interactions, student-faculty interactions and problem definition quality. Table 2 enumerates the metrics used and corresponding survey questions. A five point Likert-type scale, ranging from 1 as “strongly disagree” to 5 as “strongly agree” is used for the items 1 to 6 in Table 1 as “no refinement” to 5 as “extensive refinement” is used for item 7 in and 1 as “very poor scope” to 5 as “very well defined scope” is used for item 8.

1. **Student - Student interactions**: This scale is developed to measure the extent to which students shared and discussed project ideas with other students and identified team members for the project. Questions 1-3 in Table 2 measure the student-student interaction.
2. **Student - Faculty interactions**: This scale is developed to measure the extent to which students shared, interacted and obtained feedback from faculty members on project ideas and identified interested faculty members for the project. This is measured using a 3 item scale. Questions 4-6 in Table 2 measure the student-faculty interactions.
3. **Problem statement quality**: The amount of refinement and 

![FIGURE 3: SYSTEM IMPLEMENTATION](image)

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Blackboard</th>
<th>Global-Hub</th>
<th>Drupal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multiple user roles</strong></td>
<td>Not Supported</td>
<td>Not Supported</td>
<td>Supported</td>
</tr>
<tr>
<td><strong>All stakeholders accessibility</strong></td>
<td>Not Supported</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td><strong>Discussion &amp; chat</strong></td>
<td>Supported</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td><strong>Teams &amp; Groups</strong></td>
<td>Not Supported</td>
<td>Supported</td>
<td>Supported</td>
</tr>
</tbody>
</table>
TABLE 2: SURVEY VARIABLES AND MEASURES

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Survey Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student – Student interaction</td>
<td>1. I was able to share my project ideas with other students.</td>
</tr>
<tr>
<td></td>
<td>2. I was able to receive feedback from other students on my project idea.</td>
</tr>
<tr>
<td></td>
<td>3. I was able to identify team members who were interested in my project idea.</td>
</tr>
<tr>
<td>Student – Faculty interaction</td>
<td>4. I was able to share my project ideas with the faculty members</td>
</tr>
<tr>
<td></td>
<td>5. I was able to receive feedback from the faculty members on my project idea.</td>
</tr>
<tr>
<td></td>
<td>6. I was able to identify faculty members who were interested in my project idea.</td>
</tr>
<tr>
<td>Problem Statement quality</td>
<td>7. Rate the amount of refinement you made to your problem statement.</td>
</tr>
<tr>
<td></td>
<td>8. How focused is the scope of the problem statement.</td>
</tr>
</tbody>
</table>

The problem statement scope is measured using this scale. This is measured using a 2 item scale. Questions 7 and 8 in Table 2 measure the problem statement quality.

6 RESULTS
6.1 UTILITY OF THE ONLINE TOOL
First, students’ adaptability to the new system was examined. Figure 4 shows the frequency of use of the online platform by the second group of students who intend to take senior design course in Summer/Fall 2014. Although, some students never accessed the online tool, most of the students accessed the tool at least once a week. An active participation from students was observed in sharing project ideas and participating in discussion with the faculty. After implementation of the online tool, in a period of one month a total of 16 project ideas were proposed. 4 among 16 ideas were put forward by the faculty and 12 were proposed by the students. Additional web statistics observed for a period of one month i.e. from 1st March to 31st March 2014 is provided in Table 3. Faculty and students collectively participated in refining the problem statements. Students who accessed the online tool reported that the use of online tool was simple and useful for collaboration.

6.2 STUDENT-STUDENT INTERACTION
Table 4 presents the response of the student - student interaction. A comparison of the average student-student interactions both before and after implementing the online tool is performed. Figure 5 draws a comparison of interactions among students. An increase of 23% (i.e., from 28% to 51%) is observed in the amount of student-student interaction. After tool implementation, more than half of the students (56-65%) agreed that they were able to share their project ideas with their fellow students, as compared to (25-33%) before the implementation. A
TABLE 4: SURVEY RESPONSE

<table>
<thead>
<tr>
<th>Options</th>
<th>Before tool implementation (N=194)</th>
<th>After tool implementation (N=48)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I was able to share my project ideas with other students (1=Strongly disagree, 5 = Strongly agree)</td>
<td>24% 14% 29% 22% 11%</td>
<td>4% 4% 27% 59% 6%</td>
</tr>
<tr>
<td>I was able to receive feedback from other students on my project ideas (1=Strongly disagree, 5 = Strongly agree)</td>
<td>32% 19% 26% 13% 10%</td>
<td>4% 12% 38% 42% 4%</td>
</tr>
<tr>
<td>I was able to identify team members who were interested in my project idea (1 = Strongly disagree, 5 = Strongly agree)</td>
<td>28% 16% 27% 16% 13%</td>
<td>4% 23% 31% 36% 6%</td>
</tr>
</tbody>
</table>

TABLE 5: DESCRIPTIVE STATISTICS OF STUDENT-STUDENT INTERACTION.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Group Size</th>
<th>Mean</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>student-student interaction</td>
<td>1</td>
<td>48</td>
<td>3.34</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>194</td>
<td>2.67</td>
<td>1.23</td>
</tr>
</tbody>
</table>

As shown in Table 5, a comparison of average student-faculty interactions before and after the online tool suggests an increase of 27% (i.e., from 21% to 48%) in the amount of student-faculty interaction. Also, a two sample statistical t-test is again performed to determine whether or not the difference between mean amount of student-faculty interaction in both the groups of students is statistically significant by testing \( H_0 : \mu_1 = \mu_2 \) vs. \( H_1 : \mu_1 \neq \mu_2 \) with the level of significance \( \alpha = 0.05 \). Here, \( \mu_1 \) is the mean amount of student-faculty interaction of the group that used the online platform and \( \mu_2 \) is the mean amount of student-faculty interaction that did not use the online platform. The p-value of the t-test is observed to be 0.001 and is less than the significance level (0.05). Therefore we accept the alternate hypothesis and claim that there is a statistically significant difference in the mean amount of student-faculty interaction.

TABLE 6: DESCRIPTIVE STATISTICS OF STUDENT-FACULTY INTERACTION.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Group Size</th>
<th>Mean</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>student-faculty interaction</td>
<td>1</td>
<td>48</td>
<td>3.31</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>194</td>
<td>2.45</td>
<td>1.21</td>
</tr>
</tbody>
</table>

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Average percentage response to the questions:
Q1. I was able to share my project ideas with other students.
Q2. I was able to receive feedback from other students on my project ideas.
Q3. I was able to identify team members who were interested in my project idea.

**Figure 5**: Average Student-Student Interaction.

Average percentage response to the questions:
Q1. I was able to share my project ideas with the faculty members.
Q2. I was able to receive feedback from the faculty members on my project idea.
Q3. I was able to identify faculty members who were interested in my project idea.

**Figure 6**: Average Student-Faculty Interaction
7 DISCUSSION

After implementation of the online tool, a total of 16 project ideas were proposed. 4 among the 16 ideas were put forward by the faculty and 12 were proposed by the students. Faculty and students collectively participated in refining the problem statements. Initial findings show a statistically significant increase in the amount of student-student interaction and student-faculty interaction.

Next observation is that the frequency of using the online tool was lower than expected. This can be observed in Figure 4 which show that the majority of the students only used the online tool once per week. We expected that the students would atleast use the online tool 3-4 times per week. This may be attributed to the fact that it requires more time for any social platform to become popular, establish a community of users and promote frequent interactions between them [23]. The response to the statement “I was able to receive feedback from other students” shows that less than half of the students (42-46%) agreed to the statement. This may be because the same discussion space was provided to both students and faculty to provide feedback. This can be inferred from the students suggestion for a separate discussion space for students and faculty in the future versions of the tool. Also, it was anticipated that the students would use the discussion section to express their interest on a specific project, and this would aid the team building exercise. Since less discussion activity by students was observed, this explains the response to the statement “I was able to identify team members on my project idea”, as only 42% of students agreed to the statement.

Finally, students’ perception in using the online tool was also collected. We observed that 81% responded with affirmative that the online tool was a useful tool for collaboration. Although most of the students agreed that the online tool was useful for collaboration, only 26% agreed to the statement “I believe, I can collaborate better through the online tool than through face-face meetings”. This may be because of the low frequency in using the online platform or it could be because of delays in receiving a reply for a post or comment as mentioned in the written feedback by one of the students. This lack of spontaneity in response may hinder building a sustainable online community. Therefore to address this, some type of synchronous communication tool must be integrated in the future version of the online tool.

When asked to state a better alternative for forming engineering design project and teams, a large portion of the students stated that the online tool was probably one of the best alternatives. Other responses for better alternatives included meeting in person and sharing ideas. While there are some technical deficiencies with the current implementation, students generally found the tool to be useful.

8 CONCLUSION AND PATH FORWARD

The impact of social tools in an virtual organization is emphasized in [24]. The author states that the social tools allow us to create networks of connections and aid in finding people with right expertise at the right time. By utilizing these tools, there exist plethora of opportunities for us to explore our current environment and create new ways for experiencing it. One such opportunity is improving the engineering design project formation process. An online collaborative platform should promote a sense of community, social presence, and frequent interaction [23]. The research question we tried to answer in this study is: Does an online collaboration tool improve the project formation process in engineering design courses?

In the present study we observed that the online tool promotes collaboration by connecting appropriate stakeholders and building a network of these stakeholders, which might not be made through face-to-face meetings and e-mail communications. Initial findings show a significant increase in the amount of interactions among students and faculty. Students found the tool simple to use. While the tool appears to be very useful for collaboration, more time is required for it to become widely used. There appears to be a cultural change for the stakeholders to fully cohere from email communication to using online collaboration tool. The suggestions for improving the tool generally included features that were not necessarily design specific, indicating that the underlying concept of this online platform provides a strong basis and can be extended for future online tools.

Figure 7 illustrates the difference in the process of formulating senior design projects before and after implementing the online tool. As illustrated in the Figure 7 the online tool provided an opportunity for connecting these stakeholders at one platform which would have otherwise not been made. Although we observed an increase in interaction quantitatively, a qualitative analysis observing the responses and project statements should be performed in order to understand the quality of these interactions. Establishing successful online communities typically span an extended time frame [25]. As a result it is difficult to capture the effectiveness of these collaborative platforms by just observing for a period of one semester. We believe that more insights can be obtained if further analysis is carried over a period of time observing the online community evolving. Through further studies, the existing platform may be improved, and it could ultimately enhance the way the engineering design is carried out.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support from the National Science Foundation through the CAREER grant 1265622.
FIGURE 7: COMPARISON OF PROJECT FORMATION PROCESS BEFORE AND AFTER IMPLEMENTATION OF ONLINE TOOL.

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