First-Year Engineering Student Perspectives Of Google Docs For Online Collaboration

Ms. Natasha Perova-Mello, Oregon State University

Natasha Perova-Mello is currently a Postdoctoral researcher at Oregon State University in the School of Civil and Construction engineering. She received Ph.D. in Engineering Education from Purdue University. She previously worked at the Harvard Graduate School of Education as a Research Assistant focusing on students’ learning algebra and also taught an introductory physics course at Suffolk University, Boston, Mass. Before that, she worked as a Graduate Research Assistant at the Center for Engineering Educational and Outreach at Tufts University, Medford, Mass. Natasha received her M.S. in mathematics, science, technology, and engineering education in 2008, M.S. in electrical engineering in 2005 from Tufts University, and B.S. in electrical engineering from Suffolk University.

Dr. Sean P. Brophy, Purdue University, West Lafayette (College of Engineering)

Dr. Sean Brophy is a learning scientist, engineering, and computer scientist who teaches design and computational modeling to first year engineering learners. His research in engineering education and the learning sciences explores how students learn through interactions with technologies. He is particularly interested in how learners construct knowledge as they engage in complex problem solving. He continues to explore new methods to support human cognition with cognitive devices.
**First Year Engineering Students Practices For Using Google Docs to Support Workflow**

**Abstract**

This research study discusses collaboration practices first year engineering students report using to support their team’s workflow related to their design projects. Teams need to develop workflow practices that maximize each team member's’ potential to collaborate effectively. Technologies can provide a means for supporting a team’s workflow with a high degree of productivity and collaboration. What students need is to be apprenticed into the practice of effective team knowledge building. For example, online tools like Google docs provide multiple methods for team members to build and manage knowledge together. Students entering today’s workforce need to experience online collaboration and work management to better prepare them for virtual engineering contexts that are becoming more prevalent in engineering professions. In this exploratory study, our guiding research question is: How do engineering teams manage their workflow and generate knowledge using technology, such as Google Docs?

Google Docs was used because it can facilitate a complex and interconnected core processes of collaborative work such as team awareness of each other’s thinking and shared decision making associated with their design process and final reporting. What an effective team needs are executive skills for managing a design process that transitions their ideas into a plan, research, build, test and refine cycle. Project management tools can support the processes if team leaders know how to track and facilitate the process. One of the goals of this first year engineering course is to develop these skills in the team members so they can effectively use them for future design activities like senior design and multidisciplinary projects in industry.

In this paper, we present results from a qualitative analysis of student responses to open-ended questions designed to elicit their invented strategies they used to managing their workflow during a semester long project. Results in this study focus primarily on students’ reflections at the middle of the semester when they were in the initial stage of requirements finding, ideation, research and analysis of potential design options.

**Introduction**

Teamwork is essential to the engineering professional experience and is an important pedagogical objective in engineering courses where students need to learn how to work together and practice their communication and knowledge building skills with teams. Teamwork is one of the central ABET criteria for undergraduate engineering education where it is emphasized that students need to develop “an ability to function on multidisciplinary teams and an ability to communicate effectively” (ABET, 2016). In addition, in engineering practice “teamwork today means not only face-to-face experience, but online interaction and cooperation as well, across geographical and cultural boundaries” (TUEE Report, 2014). Distributed teamwork requires a greater effort to manage the work process and to make sure that team members communicate clearly and effectively. It becomes important to provide “virtual interaction” opportunities for student teams as part of their learning in regular face-to-face classrooms in order to help them practice sharing ideas and building solutions with the help of technology to manage their design
process.

From a theoretical perspective, learning how to work well as a team is linked to the development of positive interdependence, to achieve cohesion. That is, at the core of the cooperative learning model is a theory of social interdependence where “the transition from self-interest to mutual interest is perhaps one of the most important aspects of the theory” (Johnson et al., 2007, p. 17). A “sink or swim together” attitude in students is an important component of successful teamwork experience (Smith, K., 1996). One of the ways of supporting interdependence in student teams is by providing multiple opportunities for continuous interaction and teamwork in and outside the classroom. Technology can be used to efficiently facilitate team members’ interaction and to help them be aware of changes made to their project’s documentation. In addition, technology can also be a learning tool for team members to practice communication in a “virtual teamwork” context to help better prepare them for engineering practice in industry or research settings (Anagnos, Lyman-Holt & Brophy, 2015).

The focus of this study was to explore how teams of engineering students used Google Docs to support their collaborative work flow during the initial stages of requirements finding, ideation, research and analysis of potential design options. Students’ familiarity with the tool and Google Docs’ built-in affordances for knowledge management made it a practical solution for supporting complex interaction patterns among team members. Research question that guided the exploration of Google Docs integration by engineering teams focused on: How do engineering teams manage their workflow and generate knowledge using technology, such as Google Docs?

The results from this work were intended to inform how instructors could better implement cooperative learning environments in their classrooms using technology solutions. The following provides a brief background of cooperative learning environments blended with peer instructions as an advance method for supporting instruction. Next we aspects of effective team work flow and what effective teams need to be productive toward their shared goals. Then we present a refined framework of Stahl’s to identify the key factors that influence a team’s use of technology to support their shared knowledge building activities associated with their goals. This review of the literature provides the background for the design of this study and the rationale for the data collection and analysis methods for a self-report study.

**Literature Review**

**Cooperative Learning Model in Engineering Classroom**

According to the Undergraduate Teaching Faculty 2010-1011 survey results from the Higher Education Research Institute, the Cooperative Learning Method was one of the most frequently used approaches in STEM instruction when comparing group projects and student inquiry (Undergraduate Teaching Faculty National Norms for the 2010-2011 HERI Faculty Survey (Hurtado et al., 2012). In addition, the cooperative learning model addresses one of the central ABET criteria for undergraduate engineering education, which is to develop “an ability to function on multidisciplinary teams and an ability to communicate effectively” (ABET, 2016). Smith (1996) first introduced a cooperative learning instructional model to the engineering education community cooperation as “working together to accomplish shared goals” and cooperative learning as

...the instructional use of small groups so that students work together to maximize their own and each other’s learning. Carefully structured cooperative learning involves people working in teams to accomplish a common goal, under conditions that involve both
positive interdependence (all members must cooperate to complete the task) and both individual and group accountability (each member is accountable for the final outcome) (p. 71).

Essential elements of Smith’s (1996) cooperative learning method include positive interdependence, face-to-face promotive interaction, individual accountability/personal responsibility, teamwork skills and group processing. As Johnson, Johnson, and Smith (2007) wrote, “The heart of cooperative learning is positive interdependence”. Positive interdependence is based on social interdependence theory where “the transition from self-interest to mutual interest is perhaps one of the most important aspects of the theory” (p. 17).

Positive interdependence exists when “individuals perceive that they can reach their goals if and only if the other individuals with whom they are cooperatively linked also reach their goals and, therefore, promote each other’s efforts to achieve the goals” (Johnson et al., 2007, p. 16). This essential component of cooperative learning is the main building block of students’ experiences working in teams and an important influence in teams’ success. According to social interdependence theory, positive interdependence “results in promotive interaction” where promotive interaction is defined as “individuals encouraging and facilitating each other’s efforts to complete tasks, achieve, or produce in order to reach the team’s goals. It consists of a number of variables, including mutual help and assistance, exchange of needed resources, effective communication, mutual influence, trust, and constructive management of conflict” (Johnson et al., 2007, p. 17). Establishing positive interdependence in cooperative teams requires instructional support and understanding that different types of positive interdependence need different instructional approaches.

In an engineering classroom with cooperative learning as a preferred instructional method, more attention should be paid to how student teams develop and support their interdependence and what instructional support should be provided. Supporting positive interdependence could be one of the ways to help teams learn to work together more effectively. In this study, Google Docs software was introduced to teams as a supplemental online work management tool that students could use to work together in the shared document simultaneously and asynchronously, track history of edits and keep all of the team's documents in one central location that was easily accessible from anywhere and anytime by all of the team members. Use of online workflow management tools in the classroom can also help to better prepare engineering students for global engineering practice that becomes more prevalent. A large body of research is focused on figuring out what the skills of the global engineer should be and how to teach them in the engineering classroom (National Academy of Engineering, 2005; Johri, 2009, 2010; Downey et al., 2006; Lucena et al., 2008). What is clear is that global engineers will need to participate in virtual teams. According to Johri (2010), in the context of global engineering, “one of the primary characteristics of the global workplace is global or virtual teams—teams that are spread across different geographic locations and in which team members collaborate primarily using information technology” (p. 93). Use of technology for work coordination and communication is essential for success in virtual teams. It becomes important to start introducing elements of online interaction and cooperation in regular face-to-face engineering classes, where students can learn what it is like to work as a team in an online environment. The next section describes Google Docs’ affordances for workflow management support using Stahl’s (2004) collaborative software learning criteria framework.
Google Docs Software Affordances to Support Engineering Team Workflow Management

Google Docs has the potential for providing a rudimentary collaborative project management tool for team projects. That is, Google’s suite of tools provides a centrally located resource of tools that a team can use to collaboratively generate and manage knowledge relevant to everything they do on a project, like a term design project. The suite of tools by themselves does not provide a collaborative learning environment for the team. The team must bring their executive order to the process. The goal of our pedagogical approach in engineering education is to help apprentice the students into the ways of managing their workflow using basic tools like the suite of online applications like Google Docs and the wide range of plug-ins developed by third parties. In industry they may use systems that are more structured and comprehensive because they are needed to support very large complex projects that involve multidisciplinary teams working on the project (e.g. engineering design, manufacturing, finance, marketing etc.). The collaborative software learning criteria framework developed by Stahl (2004) provided useful definitions of affordances for social awareness, knowledge building and knowledge management that framed the design of this study. Table 1 outlines the major dimensions of the framework.

Table 1. Collaborative software learning criteria framework from Stahl (2004, p. 81)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration</td>
<td>Facilitating interactions, helping participants to maintain an overview of them, allowing participants to negotiate group decisions and building tacit knowing on the group level.</td>
</tr>
<tr>
<td>Social awareness</td>
<td>Displaying or comparing alternative interpretations of different participants in collaboration and keeping track of who knows or does what, when, where</td>
</tr>
<tr>
<td>Knowledge building</td>
<td>Accumulating, storing, organizing, preserving and displaying multimedia artifacts that arise in interaction.</td>
</tr>
<tr>
<td>Knowledge management</td>
<td>The ability to collect items from broad discourses and organize them flexibly according to various perspectives for further manipulation and sharing.</td>
</tr>
<tr>
<td>Apprenticeship</td>
<td>Defining tasks, activities and learning goals, simulating pedagogically meaningful experiences and monitoring progress.</td>
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The keywords describing Google Docs include: easy editing, anywhere and anytime access, and working on the shared document synchronously or asynchronously with the additional support of Chat and Comments features. In essence, it is a workflow management tool that can support teams’ awareness, knowledge building and knowledge management criteria that are integral and interconnected parts of the workflow process as described in Stahl’s framework in Table 1. The team must bring to the experience the executive skills, i.e. strategies, needed to elicit knowledge from all the team members and organize it in a useful way. Therefore, we related apprenticeship in Stahl’s framework with the pedagogical approach the instructional team could use to inform and engage students in a collaborative workflow process to manage a complex project like design. A description of the pedagogical approach for developing these skills is described later. First we expand on the theoretical perspective for the potential benefits of Google Docs to support a collaborative workflow process. In Google Docs, social awareness is supported through the revision history feature, where all of the changes are automatically saved and it is possible to view older revisions of the document and see who made the changes and when they were made. Each of the team members with shared document privileges can see who else is active in the document and can connect to them via a chat feature that supports real-time interaction. Another way that Google Docs supports social awareness is through the Comments feature. With Comments each team member can ask questions, provide clarification,
explanation of changes or other ideas to support the team’s shared knowledge about the specific area of the design. Comments are visible to all of the team members so everyone can respond. In addition, when the Comment is posted, team members receive an email notification about the new post so that they can respond more promptly. The comments feature provides a way to support interaction in asynchronous editing of the document.

Google Docs also allows document storage in various formats in folders that can be easily accessed anytime and anywhere by all of the team members and organized based on the member’s preferences. Within the documents, information can be added, deleted, edited, and/or commented on by all members who share the workspace. Use of Comments can provide consistency to team members’ asynchronous work patterns by posting questions or offering explanations of changes that were made to the shared document. In essence, Google Docs can provide a repository for different knowledge pieces that get created during the design process and can potentially become a central online place for the team to not only store but also to build new knowledge collaboratively. In addition, ease of access to the content helps team members to stay current with the work process, and that is an important part of the knowledge building process.

Knowledge manipulation and organization support within the Google document is facilitated by a shared online space where team members can sort through different knowledge artifacts represented in textual, pictorial, graphical or table format, and pull them together in order to build the report. Instant Chat and Comments features can support information processing and information linking. Working simultaneously on the document, students can synthesize together the content that was developed by the team using real-time text communication. Working asynchronously, team members can use the Comments feature to explain their reasoning process and knowledge organization structure.

Overall, Google Docs affordances have the potential to facilitate complex and interconnected core processes of collaborative work such as team awareness, knowledge building and knowledge management. These Google Docs affordances can be used to support engineering team workflow management by providing opportunities for a higher level of interaction and interdependence among team members, by making workflow more transparent, by reflecting the rhythm of the work process and by helping teams not only manage their workflow but actually get into the flow of higher productivity and investment in the shared work. Table 2 shows a summary of Google Docs features as advertised by Google on https://www.google.com/docs/about/. Specifically, the reference to “Do more, together” identifies the important opportunities engineering educators could leverage to develop the learners abilities to be productive in their collaborations with their team members.

Table 2. Google Docs Summary of Features from https://www.google.com/docs/about

<table>
<thead>
<tr>
<th>More than letters and words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Docs brings your documents to life with smart editing and styling tools to help you easily format text and paragraphs. Choose from thousands of fonts, add links, images, drawings, and tables. All for free.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Get to your documents anywhere, anytime.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access, create, and edit your documents wherever you go – from your phone, or computer.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Do more, together.</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Google Docs, everyone can work together in the same document at the same time</td>
</tr>
<tr>
<td>Share with anyone. Click share and let anyone – friends, classmates, co-workers, family – view, comment on or edit your document.</td>
</tr>
<tr>
<td>Edit in real time. When someone is editing your document, you can see as they make changes</td>
</tr>
</tbody>
</table>
Methods

Study Context

This study was conducted in a two semester, first year engineering course aimed at developing students’ creativity and innovation abilities. Specifically, the course focused on developing students’ ability to work in teams to find design solutions. The course also helps to develop student's ability to perform a structured problem solving process, and design computational models to analyze system performance. Each semester students were taught strategies for supporting a design process focused on innovative solutions, teaming strategies to achieve high performance on projects, and project management skills to monitor project progress. Students are then given multiple in-class design challenges and out-of-class projects to provide them with opportunities to act on these skills and reflect on their process to improve for the next design activity.

The first year engineering course is worth 3.5 credits each semester and has 3 2-hour sessions. Class sessions use a studio model of instruction and encourage peer instruction in teams for every class session. The "context" for the course is to prepare students for their academic and professional engineering careers. This means developing skills in innovative design, computational modeling/analysis, project management and teaming. Engineering students taking this class are part of residence based learning community. Therefore, the all live in the same dorm and many students have similar schedules.

In the first semester students were assigned to a team. One of their first assignments was to construct a code of cooperation that basically articulates their expectations for their teammates and the consequences for not meeting these expectations. The teams were then assigned three term projects. The first was a weeklong design task focused on building the team’s interdependence. The second project was a multi-class session to develop a computer model that aids in analyzing the feasibility of a conceptual design of a large infrastructure project. The final project was a semester long robotics project involving the construction of a robot that supports pickup and deliver functions as part of a cleanup process. This first semester experience provided students with fundamental strategies and multiple design opportunities to practice these
engineering skills and knowledge with feedback from the instructional team.

The second semester provides a similar sequence of design project experiences as the first semester, but with a new team. Similar to the first semester, the team worked on a mechatronics project to develop an autonomous lunar rover that sets up radio antennas for deep space research. Table 3 outlines the major milestones of activities associated with Project 3 across the 16 week course. The major milestones provided both a scaffold for time management for the project, and feedback from the instructional team on the quality of their work at each of these milestones. The second semester provides students with a second opportunity to apply the skills and strategies for design, teaming and project management they learned during the first semesters. Therefore, the instructional team had a higher expectation of the student team’s ability to regulate their design process. The major milestones provided this opportunity to monitor their progress and provide feedback similar to the first semester.

In the first semester the teams were formed based on a background survey to help balance the teams based on prior programming experience, gender, ethnicity, and math/science skills. In the second semester teams were formed to provide a balance based on prior course performance, gender and ethnicity and no members in the fall will be on the same team with a prior team member. In the fall semester students were provided with training on effective teaming and given multiple opportunities to work as a team in class. Teams were also given training on psychological safety and methods for effective team meetings. CATME was used during both semesters. It was used two times for Peer Evaluation of each other team member.

Table 3 - Timeline of major milestones related to Project 3

<table>
<thead>
<tr>
<th>Week</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Form teams and introduce Project 1, generate code of cooperation</td>
</tr>
<tr>
<td>2</td>
<td>Introduce term Project 3 and instructions for using Google Docs to manage their project electronic notebook and formal project report.</td>
</tr>
<tr>
<td>3</td>
<td>Design challenge 1, demonstrations of Project 1</td>
</tr>
<tr>
<td>4</td>
<td>Initial design review of Project 3 requirements specification</td>
</tr>
<tr>
<td>6</td>
<td>Notebook review of Project 3</td>
</tr>
<tr>
<td>7</td>
<td>Design challenge 2</td>
</tr>
<tr>
<td>8</td>
<td><strong>Mid semester Reflection Survey</strong> on Project 3 design process using Google Docs</td>
</tr>
<tr>
<td>9</td>
<td>Spring Break</td>
</tr>
<tr>
<td>10</td>
<td>Project 3 performance review 1 of subsystems</td>
</tr>
<tr>
<td>11</td>
<td>Project 2 in class investigation</td>
</tr>
<tr>
<td>12</td>
<td>Project 2 in class investigation</td>
</tr>
<tr>
<td>13</td>
<td>Project 3 performance review 2 of subsystems- out of class Design challenge 3</td>
</tr>
<tr>
<td>14</td>
<td>Project 3 report draft turned in for feedback</td>
</tr>
</tbody>
</table>
Data Collection

The goal of this research study was to explore first year undergraduate engineering teams’ use of Google Docs to support their collaborative workflow during a semester long design project. Data collection was conducted during the Spring 2016 semester. Data collected consisted of teams’ Google Docs, and Reflection surveys administered during mid semester and end of Spring 2016 semester. Table 4 provides information about when each of the data sets were collected, how the data collection process was administered and how many teams/students participated in the data collection. Mid-semester and end-semester Reflection Surveys are identical. The focus of this study is on analysis of mid-semester Reflection Survey.

In the Fall 2015 semester Google docs was recommended as a tool for supporting collaboration. In the Spring 2016 semester it was required for one of the sections and access privileges were shared with the two members of the instructional/research team. The instructor did not give any explicit instructions on how to use Google docs to support the process. No extra credit was given for taking the mid-semester and end-semester Reflection surveys, but class time was provided for students to take these surveys. The completion of the surveys was voluntary.

Reflection Survey was developed with the goal to provide students working in teams an opportunity to reflect on their experiences using Google Docs to support their teams’ workflow process as well as to rate their teams’ management in categories such as time, setting goals, decision making, communication face-to-face and with support of technology, ideas and opinions sharing, problem solving and conflict management. A mix of Likert scale and open-ended types of questions were included in the survey. Mid semester and end semester Reflection Surveys are the identical in content. Mid semester Reflection Survey was administered online during week 8 of classes and end semester Reflection Survey was administered during week 16 of classes.

All of the surveys were administered using Qualtrics Survey system. The instructor was provided with the web address for each of the surveys during different weeks of the semester and then the instructor gave students the web address for each of the surveys at different times. For example, students got the link to the mid semester Reflection survey and completed it online during week 8 and students completed end semester Reflection Survey during week 16.

During Spring 2016 semester there were 17 teams in total with three to four students in each of the teams. The instructor set up a collection Google drive folders that were shared with all team members. The teams were recommended to use these folders to store their working documents for the project. Two of the teams had already started their own folder for their Project 1 work and the instructor requested these teams to share their folder with the instructor. These shared folders provide the instructor with the opportunity to monitor a team’s workflow as it evolved over time.

Table 4. Data Collection Process
<table>
<thead>
<tr>
<th>Data Collected</th>
<th>When Data Was Collected</th>
<th>Participation Rate</th>
<th>How Data Was Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Docs</td>
<td>Throughout the semester</td>
<td>15 teams</td>
<td>Online shared Google Docs</td>
</tr>
<tr>
<td>Reflection Survey</td>
<td>Week 8</td>
<td>41/64 students</td>
<td>Qualtrics Online Survey</td>
</tr>
<tr>
<td>(mid-semester)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflection Survey</td>
<td>Week 16</td>
<td>39/64 students</td>
<td>Qualtrics Online Survey</td>
</tr>
<tr>
<td>(end-semester)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Data Analysis Method**

Data analysis used in this study followed Miles et al.’s (2014) construct consisting of “data condensation, data display, and conclusions drawing/verification” activities (Chapter 1, Section 7, para. 1). According to the authors, all of these activities are part of the interactive, cyclical process of analysis. The goal of data condensation is to “sharpen, sort, focus, discard, and organize data...so that conclusions can be drawn and verified” (Miles et al., 2014, Chapter 1, Section 7, para. 2). The goal of the data display activity is “to put together organized information into an immediately accessible, compact form so that the analyst can see what is happening and either draw justified conclusions or move on to the next step of analysis that the display suggests may be useful” (Miles et al., 2014, Chapter 1, Section 7, para. 6). The purpose of the conclusions drawing/verification activity is to test “the meanings emerging from the data for their validity” (Miles et al., 2014, Chapter 1, Section 7, para. 10). In this study, data types collected consisted of quantitative and qualitative types. More specifically, quantitative data from each team’s Google Docs included the history of revisions and qualitative data consisting of interactions posted in Comments. Similarly, the Reflection Survey consisted of questions that required students to rate their responses and also questions that required open-ended responses. Open coding during the data condensation process was done using First Cycle and Second Cycle Analysis methods suggested by Saldana (2010, Chapter 3, The Coding Cycles, para. 2). In this study we present the analysis of the mid-semester Reflection Survey.

**Results**

**Teams’ Culture**

In the mid-semester Reflection Survey, we asked students several questions to gain insight about interaction dynamics within their team. These questions asked about comfort levels of interacting with each other on project related topics as well as non-project related things, frequency of meeting face-to-face to work on projects outside the class time; and also norms and behaviors that teams followed regularly based on the established early in the semester Code of Cooperation document.

We found the majority of students (76%) met more than 7 times outside the classroom time to work on Project 3, 15% of students met 5-6 times and 10% met 3-4 times while working on the project. It was also found that 75% of students felt comfortable (responded “definitely yes”) interacting with their teammates about project work and 71% felt comfortable expressing their opinions and ideas during team meetings. As for the interaction among teammates related to non-project topics, 54% of students said that they definitely felt comfortable and 37% said probably comfortable.

In their responses to an open-ended question about norms and behaviors that teams followed regularly students consistently referred to the importance of psychological safety, clear
communication, and work ethic. Some of the examples of these comments include:

- “We listen to one another and designate individual tasks”
- “We respect each other and come to meetings prepared”
- “We reinforce positive performance and attitudes”
- “We promote psychological safety”
- “We have been respectful to each other and have done everything that will enhance the experience of teamwork”

Many of these responses represent language students used during classroom discussion about qualities of well functioning teams. The explicit reporting of these ideas in their code of cooperation and in their survey responses suggests students are implementing these concepts as part of their interactions with each other. In their responses related to work ethic, several students commented on the importance of having “no outside distractions such as phones” during team meetings as well as meeting regularly and communicating clearly with each other. The collection of student generated expectation of each other has been very useful to the instructional team for gathering insights into evaluating the quality of the Code of Cooperation and providing feedback to teams.

**Student Perceptions About Teams’ Management**

Mid-semester Reflection Survey included several questions asking students to provide feedback about their team’s dynamics. One of the questions asked students to rate how well they thought their team managed time, setting goals and work planning, decision making, face-to-face communication and communication with technology, ideas and opinions sharing, problem-solving strategy and conflict management. Students were provided with options such as very good, good, fair and poor for each category factor. Figure 1 shows results based on student ratings for different team management categories.

Figure 1: Student rating responses for team management question

Open-ended questions asked students to discuss strengths and weaknesses of their team dynamics. Analysis of student open-ended responses to questions about team strengths showed that students frequently identified setting goals and work planning, as well as good collaboration among team members. Some of the examples include:

- “We are very good at managing a heavy workload and getting multiple things done at
once. Interdependence is strong in this team.”
“Our team is good at organizing and dividing work to efficiently complete tasks”
“We have a good balance of skill sets, ranging from strong programmers to good technical writers to great mechanics, and it allows us to provide a well rounded and successful deliverable.”
“We work together well and get along. We are good at splitting up tasks and responsibilities.”

Analysis of student open-ended responses to questions about team weaknesses showed that students most frequently referred to problems with time management, followed by problems with sharing ideas and opinions and communication. Some of the examples include:
“We can't always meet face to face, and this causes miscommunication. Some members are frequently unavailable which can also cause problems with workload distribution.”
“One weakness is our usage of time. Sometimes we get a little distracted or not too focused on the task at hand.”
“We occasionally suffer from group think.”
“Sometimes, because we split up work so much, our communication is not the greatest such that some of us know less than others about what each member is doing.”

**Students’ Perceptions About Usefulness Of Google Docs**
Mid-semester Reflection Survey results showed that 95% of first year engineering students in our study used Google Docs to support their teams’ workflow. Five percent of students indicated using Groupme for communication support. From the 95% of students who used Google Docs, 92% said that they decided to use it because the majority of team members preferred it and 3% said that a team member who would start teams’ Google Doc right away as a method to organize their work influenced their decision.

Establishing norms/rules/behaviors are necessary to manage a collaborative environment such as Google Docs, otherwise expectations are not met and work is not completed. Fifty six percent of students said that they established their norms and rules when they first started using this environment and 44% of students said they did not establish any rules for how to manage their work in Google Docs in the beginning of their project. Examples of direct quotes from students who said they established Google Docs usage rules in the beginning include the following:
“We started a folder structure that helps organize our projects and we have committed to this system. We also have agreed to use the environment consistently so that everyone has access to everyone's work.”
“All ideas are appreciated, everyone should contribute to the discussion. We will post all group work on the Google docs.”
“Everyone has to contribute to the project, so being able to work on it at the same time, and assigning homework where people could all look at it in the same document.”
“Posting all important project documents in folders, keep notebook in Google doc, document changes and iteration, take pictures. All prevalent info goes into Google doc”
“All work is shared”

Examples of direct quotes from students who said they did not establish Google Docs usage rules
in the beginning but developed them as part of their work process:

“Ask others before you change their work, always check with the team before making additions or changes.”

“Follow the template/outline that we developed. Don't delete anything Inputting ideas as generated, only delete if entire group agrees.”

“We all work on it at once, adding to whatever we happen to be working on. For reports, we divide and conquer, then all go through the report in edit mode.”

“Sharing all relevant information for the project in a document or file. Keeping everything organized into appropriate folders and keeping documents up to date when time allows.”

“Each person generally has a specified section to work on, and when the final product is nearly complete anyone is allowed to edit any other section.”

When asked about typical mode for the teams to use Google Docs, 88% of students said that they are typically working at the same time from the same location, 7% said that they are working at the same time from different locations and 5% of students described their work mode as a combination of working at the same time at the same location, working at the same time from different locations and working at different times and from different locations, depending on team members individual schedules. As one of the students said: Google docs allowed us to get work done even if not all the members were able to meet.”

When students were asked to indicate how they used Google Docs, all of the participants in the survey said that their teams used Google Docs to store project documents so it is easy to access and to write meeting notes, 95% said that they used Google Docs to keep a record of relevant information and experimental data as well as to co-write the project report. Additionally, some of the students commented that they considered Google Docs as “a way for people from different areas to communicate. For example, one of the teammates does not live on campus so it helps to use Google docs as a way to stay connected and work together with different schedules.” Another student added that the team also used it “for everything- and I mean everything”, for example to “co-write the project presentations, store code for the robot. Store pictures of design process.”

Students were also asked about the roles that they have when they use Google Docs. For example, do they primarily contribute content or focus on editing of the existent content, or keep a general organization and formatting of the document up to date? Majority of students said that they rotate their roles and participate in writing, editing and formatting of the content. In such cases teams seem to rely more on a distributed model of Google Docs use and maintenance. As one of the students mentioned: “We generally each do some of it. We don't have Google Doc "roles" because they are unnecessary.” In other situations, it appears that teams assigned roles to members to manage their shared Google Docs folders, for example:

“I attend all meetings and make sure all info is in the docs, and organize the design notebook and folders”

“I personally set up the organization of the folders with the team's approval.”

“I do a lot of documentation in project meetings and create a lot of the graphics such as flowcharts and tables. Also, I regularly review and draft project reports.”

A set of the questions in the survey asked students about the use of ‘comments’ feature in Google Docs. The first question asked about what was included in comments if this feature was
used by the team? Eighty seven percent of the students said they used Comments as a way to explain the meaning of added to the shared document text or formula in order to clarify content. Eighty percent said they used comments primarily to ask team members to make small edits related to citations, units and general formatting. Forty percent of students said they were trying to use comments to explain their contributions to the shared document so that other team members could better understand any new changes that were made. One student mentioned using ‘comments’ feature to organize their team’s work tasks and keep track of the progress: “We use comments to include what needs to be done in each section, and when that is added, it will be marked as resolved.”

When students were asked to rate whether their use of ‘comments’ feature had any effect on their levels of awareness about the thinking process of the team members, problems team members were trying to resolve, overall team’s work process and individual thinking and work progress, students responses varied across categories. More students agreed or felt neutral about the usefulness of comments for supporting awareness of individual and teams working processes. Figure 2 shows the summary of results.

Figure 2. Student rating responses about the use of ‘comments’ in Google Docs

Students were also asked in an open-ended question to reflect on ways the comments feature supported their thinking process. Several descriptive categories emerged from the analysis of responses. These categories include: work transparency, communication opportunities, and work process management.

Responses that were included in the work transparency category, typically discussed the benefit of ‘comments’ feature to help make visible individual work process as well as questions that team members might have. As one of the students said: “It allows others to see what ideas you are unsure of and help you get the help you need”.

Communication opportunities category includes responses that focus on the role of ‘comments’ feature as a way to interact with teammates anytime/anywhere, share ideas, provide personal opinions about the state of the shared document and ask questions or clarify parts of the content.

Work process management category, includes responses that point out the role of ‘comments’ feature in organizing individual and/or teams’ work. For example, in one of the responses, a student reported that comments: “provides an indicator of group progress and
quality of the product”. Another student added: “The comments feature allows me to record things that I want to do on the document in the future, or write questions on what I don't understand.”

**Discussion**

Collaborative learning environments engage teams in a process of shared knowledge building toward a desired goal. The first year engineering students in this study had experiences learning how to manage a design process and had multiple opportunities to practice this process in the first course in the series. In the second course they had a chance to refine their process with a new team. Results from the second semester, Mid Semester Reflection survey provided an interesting glimpse into how they adapted Google docs as a tool to support their shared knowledge generation and management as part of their workflow for the project. Observations from this study highlight the potential for students to use Google suite as a collaborative environment where access to information and their collective knowledge is in a central location. Further, the pedagogies used to set it up and the strategies students report using provide a good foundation for how to use it as a way to apprentice students into a professional practice they will no doubt use in their career. The following discussion highlights key results associated with how teams generate and build knowledge using Google Docs as their collaborative design space.

The high preference for using Google Docs by the team's (92%) most likely indicate students are familiar with it and can see its potential for supporting their process. The documents editing environment only provides the tools for representing information in text or images the team may import from work they do on whiteboards or other digital tools like Lucid charts. More importantly, team members can each share their individual thoughts with the team by tagging their contributions to the text using the “suggesting” and “commenting” features of Google Docs. These are some of the fundamental features of a technology mediated collaborative learning environment.

What the team needs to bring to this collaborative learning environment is a process and set of norms for managing how they will generate and share information with each other and how they will make decisions about the meaning of what the team thinks. More than half of the students reported they established norms and rules for how to manage their team workflow using Google Docs early in their process. Others tended to invent a process along the way. Their responses emphasized the importance of respecting everyone’s contributions to the project, understanding the transparency in the work process and being consistent about organization of documents in shared folders.

For example, in their responses students focused more on the editing process in a shared document and the importance of not making changes or deleting somebody else’s work without letting them know about it, as illustrated in their suggested norms: “Ask others before you change their work, always check with the team before making additions or changes”, “Don't delete anything” or “only delete if entire group agrees”. Forty four percent of participants said that they did start with any specific rules for using Google Docs, but developed rules and norms over time. In either event, teams recognized that when a team member made a contribution, the rest of team members will become aware of each other’s contribution and work collaboratively to synthesize it into the collective work products.

Teams also need to establish a shared organizational structure to the documents they will be sharing (e.g team notebook, document drafts, notes from individual research, images, videos,
test results, etc). All of the participants in the survey said that they used Google Docs to store project documents so it is easy to access and to write meeting notes and 95% said they used Google Docs to keep a record of relevant information and experimental data and to co-write the project report.

Team roles, or shared responsibilities, provide a system to ensure contributions are made to the team's collective work product. As far as the student participation in content contribution, editing and formatting, majority of students said that they rotate their roles and get a chance to participate in different aspects of content management. As one of the students said: “We generally each do some of it. We don't have Google Doc "roles" because they are unnecessary.” Still others selected a team member to have the responsibility to maintain the content in the folders and assure consistent methods are used so the team does not loose information or becomes confused about what is the most current representation of the team’s work products.

Google docs can provide a shared workspace that facilitates discussion, clarity of ideas and knowledge construction. The majority of students (88%) typically used Google Docs, at the same time from the same location. The tool became a way to support collaborative work during their face-to-face meeting. In the first semester students were given the recommendation to have team roles like a notetaker. The person fulfilling this role has a huge responsibility because they must make decisions about what is worth recording and how to phrase it. During their team meetings each student had their own laptop opened to the team’s notebook and could monitor what the notetaker was contributing to the notes.

The shared access to the team’s knowledge resource provides continuous knowledge building even when the team is not able to meet. Students also commented that Google Docs helped them to stay connected to the work and communicate better, especially in the situations when they couldn’t find time to meet face-to-face.

‘Comments’ and ‘suggestion’ feature in Google Docs provided an opportunity for asynchronous communication among team members. In our study, 87% of students said that they used comments as a way to explain the meaning of added text or formula in order to clarify content and 80% said they used comments to ask team members to make small edits related to citations, units and general formatting. Asynchronous communication could be integral to support an online collaborative work and making sure that all team members are staying current on any changes and contributions that were made to the shared document. Analysis of results to question related to effect of ‘comments’ feature use on the level of awareness in categories such as own work progress and thinking process, as well as teams’ work progress, showed that students mostly agreed or felt neutral about those statements as shown in Figure 2. Because our study participants indicated the preference for using Google Docs when they are meeting face-to-face and they would typically meet frequently outside of classroom time to work on the project, they probably did not need as much to rely on asynchronous communication, for example use of ‘comments’ feature, as a way to clarify changes made in the shared document and support their level of social awareness in teams’ workflow management.

Conclusion

As professional engineers students will need to lead and participate in collaborative projects. They will use technology to manage their work products in a way that supports their knowledge generation and a record of their process so others can access their analysis and decisions. They need to develop the skills to manage this process early in their academic career.
This first year engineering course has explicitly taught teaming as part of the course and used design projects as a method for getting students to practice these skills. The use of Google Docs has provided a very accessible tool that can facilitate a complex and interconnected core processes of collaborative work. Google Docs can support an engineering team’s workflow management by providing opportunities for a higher level of interaction and interdependence among team members, by making workflow more transparent, by reflecting the rhythm of the work process and by helping teams not only manage their workflow but actually get into the flow of higher productivity and investment in the shared work. Stahl’s framework for collaborative learning environments highlights key dimensions for establishing and sustaining a collaborative online work space that is one of the critical dimensions is “apprenticeship”. Simply having access to collaborative environments like Google Docs does not ensure teams will naturally generate a productive collaborative work environment. They need to learn about, and develop, the executive skills necessary for managing the collective production of knowledge the team needs to create a shared work product like a design and its supporting documentation.

In our future works we will use analysis of teams’ Google Docs to gain insight into collaborative micro processes of knowledge organization and building in a shared online environment. We will use findings to inform engineering pedagogical practice to help facilitate a more effective use of Google Docs to support team workflow and additionally to contribute to the development of new workflow support technologies that will be focused on the needs of engineering students.

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