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Using Google Docs to Support Work Flow Management in Teams of Engineering Students

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USING GOOGLE DOCS TO SUPPORT WORK FLOW MANAGEMENT IN TEAMS OF ENGINEERING STUDENTS

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TABLE OF CONTENTS

Page

Page

Page

Page

LIST OF TABLES

Table Page

Table Page

Table Page

LIST OF FIGURES

ABSTRACT

Perova-Mello, Nataliia P. Ph.D, Purdue University, December 2015. Using Google Docs to Support Work Flow Management in Teams of Engineering Students.
Major Professor: Ruth Streveler.

The purpose of the present study was to investigate how teams of engineering students integrated Google Docs to support their workflow management process. ABET criteria dictate that engineering students need to learn how to work together and practice effective ways of communication. Learning how to work well as a team is linked to the development of positive interdependence, which is at the core of the cooperative learning model and is based on social interdependence theory. A "sink or swim together" attitude in students is an important component of a successful teamwork experience (Smith, 1996). One of the important aspects of supporting interdependence in teams is to provide multiple opportunities for interaction in and outside the classroom.

In this study, the use of Google Docs software was explored as a way to support workflow management during the collaborative report-writing phase by teams of engineering students enrolled in an undergraduate sustainable engineering course at a large midwestern university. Design-Based Research (DBR) was used in this exploratory case-based study as an approach to explore the dynamic of the "learning ecology" (Cobb

et al., 2003), and to help inform the development of an instructional framework on how to integrate Google Docs to better support teams' workflow management.

The results of this study point to the need for instruction to emphasize to student engineering teams not only the technical "how to" knowledge of the tool but also the power of the tool's affordances. The term "tool usage metacognition" has been coined to describe an attribute teams should develop to use software to support their workflow management more effectively in a blended learning environment.

CHAPTER 1. INTRODUCTION

1.1 Overview of The Study

The purpose of this study was to explore the use of online work management tool to support engineering teamwork. Google Docs software was used to help engineering student teams manage their workflows more efficiently in a blended learning environment during the collaborative report-writing phase of their work process. To investigate the integration patterns of Google Docs by teams, the Design-Based Research method was used. The study was conducted in an undergraduate engineering course on sustainable engineering in a large midwestern university. The results of this study contributed to the building of an instructional framework to support effective use of Google Docs affordances for teams' workflow management.

1.2 Problem Statement

The motivations for this study emerged from an instructional need to help teams better support their workflows, from changing demands in engineering practice emphasizing the importance for learning how to communicate in face-to-face and virtual teamwork contexts and from a theoretical interest in developing better understanding of the ways engineering teams interact with online workflow support tools. Each of these research motivators is discussed below in more detail.

1.2.1 Engineering Instruction

This research came largely from collaboration with an engineering instructor in a large midwestern university who was teaching a sustainable engineering class for undergraduate engineering students. Teamwork was central to the structure of this course. Students worked in the same teams, assigned by the instructor, on projects related to the topics of food, water, energy and sustainability throughout the semester. Originally, the instructor was concerned about the management of the teams' report writing process. In prior semesters of this course, for many teams the report writing process lacked transparency of individual efforts to the instructor and team members. Frequently students relied on the "typical" model where one of the team members would be responsible for putting individual contributions together the night before the submission rather than working as a team on co-construction of the report over a period of time. In addition to the problem of individual contributions' transparency, students kept bringing up an issue of the difficulty of finding time to meet face-to-face as a team due to their consistently busy school schedules throughout the semester. To help address the issues of the teams' workflow management, use of Google Docs was suggested as a way to support report co-writing more efficiently.

1.2.2 Engineering Practice

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. 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, 2014). 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.

1.2.3 Successful Teamwork

From a theoretical perspective, learning how to work well as a team is linked to the development of positive interdependence, that is, a core of the cooperative learning model which 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" (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 important 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 the team's project. In addition, technology can also be a learning tool for team members to practice communication in a "virtual teamwork" context to help better prepare students for engineering practice.

1.3 Research Purpose and Research Questions

The focus of this study was to explore how teams of engineering students used Google Docs during their collaborative report-writing phase and to use the analysis results to build a framework for instructors to integrate Google Docs to better support teams' workflow management. 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 questions that guided the exploration of Google Docs integration by engineering teams consisted of the following:

(1) How and to what extent do these teams integrate Google Docs into their workflow?

(2) How do these integration patterns differ depending on parameters like team performance and team dynamics?

1.4 Overview of Methodology

The exploratory nature of research questions and the naturalistic setting of the research context, a sustainable engineering class for undergraduate engineering students, led to the selection of the Design-Based Research (DBR) method. This approach helped to "capture the dynamic of learning ecology" (Collins et al., 2004) and to contribute to the educational improvement by developing a theoretical understanding for the collaborative workflow processes in engineering teams and building an instructional framework with practical research-based suggestions for engineering instructors on how to integrate Google Docs to better support teams' workflow management.

1.5 Organization of the Dissertation

In the next chapter, a review of the literature addresses background and theories needed to inform this researcher's thinking about the research questions. This review was focused on teamwork literature and technical support for knowledge building and knowledge management in teamwork literature. Areas of research discussed include cooperative learning and positive interdependence, successful team discipline and communication patterns, "teaming" as a new model for flexible teamwork, workflow interdependence in engineering teams, collaborative knowledge building, collaborative software learning framework, and asynchronous online learning. In Chapter 3, the selection of the Design-Based Research (DBR) method for the study is discussed and a description for each of the data collection phases is presented. In Chapter 4, the goal was to answer research questions explicitly. Data results are shown and an explanation of analysis is provided. Chapter 5 addresses the implications of findings. In particular, the instructional framework development is discussed and instructional suggestions on Google Docs integration are provided as well as discussion about the next steps for research.

CHAPTER 2. LITERATURE REVIEW

2.1 Overview

To focus on how and to what extent engineering student teams integrate Google Docs in their workflow and how these patterns differ depending on team performance and dynamics, and to build an instructional framework for integrating Google Docs to better support teams' workflow management, it became important to establish relevant research goals concepts, note the gaps in the existing literature and help to situate the study in the current conversations on the topic. More specifically, the literature search was focused on research areas such as engineering teamwork, collaborative knowledge building and workflow management tools, and interaction between "the team and the tool" in a context of engineering education.

The organization of this chapter consists of the following: In Section 2.2, Smith's (1996) Cooperative Learning Model is introduced. It is a widely accepted model for active, team-based pedagogical practice in engineering education. The role of "positive interdependence" (Johnson et al., 2007) in the Cooperative Learning Model is explained and referred to throughout this chapter as one of the central elements to the successful student teamwork experience. Section 2.3 focuses on successful teamwork and ways to cultivate it. The importance of discipline shared by teams based on the work by Katzenbach and Smith (1993) is discussed, followed by Pentland's (2012) revolutionary work that showed that teams' success can be analyzed with sociometric data of their communication patterns. Finally, a new perspective on what modern teamwork means is introduced in Edmondson's (2012) work which argues that with advances in communication technologies that allow global interaction, teamwork experience should take into account new possibilities for working together as well as considering the limitations presented by such contexts. The author suggests considering flexible teamwork or "teaming" as a new approach to building and supporting successful teams.

In Section 2.4, Edmondson's (2012) "teaming" lens was used to look at the types of workflow patterns or "the hardware of the teaming" in teams. Work by Borrego, Karlin, McNair, and Beddoes (2013) helped to fine-tune the definition of workflow patterns specifically for engineering teams. These workflow patterns or "workflow interdependence levels" are defined as "pooled, sequential and intensive" (Borrego et al., 2013). They differ in the levels of the reliance of team members on each other and on the levels of communication. Pooled workflow is characterized by low levels of reliance and interaction similar to the "divide and conquer" approach, and an intensive level is "usually what engineering instructors envision when they assign projects to student teams" (Borrego et al., 2013, pp. 490-491), where levels of reliance on each other and levels of communication are high.

Focusing on the importance of workflow interdependence in teaming experiences and ways to support it, especially in situations where team members have difficulties finding time to meet outside the classroom, Google Docs software was explored as an option to provide additional workflow support. In Section 2.5, Google Docs affordances to support workflow are analyzed using the "collaborative software learning criteria" framework developed by Stahl (2004). This analysis showed that Google Docs affordances have a potential to facilitate complex and interconnected core processes of teamwork such as team awareness, knowledge building and knowledge management that could help the teams not only manage their workflow but also actually get into the flow of higher productivity and investment in the shared work.

A discussion of why gaining an experience in using of a shared online knowledge management tool is important and relevant for engineering practice is presented in Section 2.6. Emphasis is made on the importance of providing students with experience in coordination and communication activities in an online environment that is essential in supporting virtual teamwork as part of global engineering. In addition, attention is brought to the importance of integrating digital technology in the classroom culture to provide “millennial engineering” students opportunities to use their experience with technology in an educational setting.

In Section 2.7, the background of the literature research process to support this study is discussed focusing on the areas of Computer-Supported Collaborative Learning and Community of Inquiry research. These areas helped to inform the researcher and also to identify the need for more work on instructional support to help teams use online tools such as Google Docs more efficiently in a context of engineering education.

2.2 Cooperative Learning Instructional Approach in an Engineering Sustainability Class

This study was set in a naturalistic setting – a real engineering classroom – and the motivation for this research came strongly from the instructor of the engineering course. This instructor wanted to increase teams’ work accountability by increasing the transparency of individual contributions to the teams' report, making sure that students took time to work on the assigned projects, worked together to write the report, and had options to co-edit the report without necessarily meeting face-to-face since they frequently complained about busy schedules that prevented them from meeting. Integrating Google Docs was a solution proposed by the researcher since this online platform offered features that addressed the needs.

The instructional strategy used in this course was very similar to the cooperative learning model that is one of the prevalent instructional methods used in engineering education. 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, 2014).

Smith (1996) first introduced the cooperative learning instructional model to the engineering education community, defining it thus:

> Cooperation is working together to accomplish shared goals" and cooperative learning is "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).

In Table 2-1, essential elements of Smith's (1996) cooperative learning method, such as positive interdependence, face-to-face promotive interaction, individual accountability/personal, responsibility, teamwork skills and group processing, are described in detail.

Table 2.1 Essential Elements of the Cooperative Learning Method from Smith (1996, pp. 75-76)

Positive Interdependence
The heart of cooperative learning is positive interdependence. Students must believe that they are linked with others in such a way that one cannot succeed unless the other members of the group succeed. Students are working together to get the job done. In other words, students must perceive that they sink or swim together. In formal cooperative learning groups, positive interdependence may be structured by asking group members to agree on an answer for the group (group product-goal interdependence); by making sure that each member can explain the group's answer (learning goal interdependence), and by fulfilling assigned role responsibilities (role interdependence). Other ways of structuring positive interdependence include having common rewards such as a shared grade (reward interdependence), division of labor (task interdependence) or shared resources (resource interdependence).
Face-to-face Promotive Interaction
Once a professor establishes positive interdependence, he or she must ensure that students interact to help each other accomplish the task and promote one another's success. Students are expected to explain to one another how to solve problems; discuss with one another the nature of the concepts and strategies being learned; teach their knowledge to classmates; and help, encourage, and support each other's efforts to learn. Silent students are uninvolved students who are not contributing to the learning of others or themselves.
Individual Accountability/Personal Responsibility
The purpose of cooperative learning groups is to make each member a stronger individual in his or her own right. Students learn together so that they can subsequently perform better as individuals. To ensure that each member is strengthened, students are held individually accountable to do their share of the work. The performance of each individual student is assessed and the results given back to the individual and perhaps to the group. The group needs to know who needs more assistance in completing the assignment, and group members need to know they cannot hitchhike on the work of others. Common ways to structure individual accountability include giving an individual exam to each student, randomly calling on individual students to present their group's answer, and include giving an individual oral exam while monitoring group work. In the example of a formal cooperative learning lesson provided shortly, individual accountability is structured by requiring each person to learn and teach a small portion of conceptual material to two or three classmates.
Teamwork Skills
Contributing to the success of a cooperative effort requires teamwork skills. Students must have and use the needed leadership, decision-making, trust-building, communication, and conflict-management skills. These skills have to be taught just as purposefully and precisely as academic skills. Many students have never worked cooperatively in learning situations and therefore lack the needed teamwork skills for doing so effectively. Faculty often introduce and emphasize teamwork skills through assigning differentiated roles

Table 2.1 Continued

to each group member. For example, students learn about the challenge of documenting group work by serving as the task recorder; about the importance of developing strategy and talking about how the group is working by serving as the process recorder; about providing direction to the group by serving as the coordinator; and about the difficulty of ensuring that everyone in the group understands and can explain by serving as the checker.
Group Processing
Professors need to ensure that members of each cooperative learning group discuss how well they are achieving their goals and maintaining effective working relationships. Groups need to describe what member actions are helpful and unhelpful, and to make decisions about what to continue or change. Such processing enables learning groups to focus on group maintenance, facilitates the learning of collaborative skills, ensures that members receive feedback on their participation, and reminds students to practice collaborative skills consistently. Some of the keys to successful processing are allowing sufficient time for it to take place, making it specific rather than vague, maintaining student involvement in processing, reminding students to use their teamwork skills during processing, and ensuring that clear expectations as to the purpose of processing have been communicated. A common procedure for group processing is to ask each group to list at least three things the group did well and at least one thing that could be improved.

2.2.1 The Role of Positive Interdependence in the Collaborative Learning Model

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). Smith (1996) stated it this way: “students must perceive that they sink or swim together”. 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 group'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. Smith (1996) stated that group product-goal interdependence is structured by "asking group members to agree on an answer"; learning goal interdependence is structured by "making sure that each member can explain the group's answer"; role interdependence is structured by "fulfilling assigned role responsibilities"; and that reward, task and resource interdependence are structured correspondingly by having "common rewards such as a shared grade, division of labor shared resources" (p. 75).

The cooperative learning model was integrated in the Engineering Sustainability course used in this study. Although collaborative instruction was not explicitly mentioned in the syllabus, the course design included the main elements of cooperative instruction. Students worked in teams on several structured projects throughout the semester. Each of the teams had to write team contracts that required students to write down their background information, such as major, learning style, and strengths and weaknesses as well as their contact phone number. Team roles were assigned in the contract, and included leader, writer, organizer, timekeeper and secretary/researcher. Team also had to write rules of conduct about attendance and timelines, communication, effort, accountability and assessment and respect for others. In addition, strategies for conflict prevention and resolution had to be worked out by team members. Once the teams completed writing their team contracts, they had to email them to the course instructor for approval. Students in each of the teams had a shared goal of completing a report for the assigned projects and all team members got the same grade for the report that they wrote together. Team members had opportunities to meet face-to-face during class time and also outside if they could arrange it. In addition, students used online environments, text messaging and phone communication to support their work on the projects.

2.3 Teams and Successful Teamwork

Teamwork is very important to engineering educational practice. One of the central ABET criteria for undergraduate engineering education is for students to develop “an ability to function on multidisciplinary teams and an ability to communicate effectively” (ABET, 2014). Successful teamwork experience depends on various factors, such as students’ ability to communicate with each other effectively, knowledge of the content, ability to manage the work process and leadership to motivate the team. These are just several of the factors that could affect the performance of the team. In addition, the setup of the course (face-to-face, blended or online) could affect team dynamics and require different kinds of instructional support. Sections 2.3.1, 2.3.2 and 2.3.3 will discuss research findings and innovations that could be appropriate for better understanding the nature of modern engineering teamwork.

2.3.1 A Cooperative Learning Group and Team Discipline

In “Pedagogies of Engagement: Classroom-Based Practices”, Smith, Sheppard, Johnson, and Johnson (2005) state that “the five essential elements of a well-structured formal cooperative learning group”, such as “positive interdependence, face-to-face promotive interaction, individual accountability/personal responsibility, teamwork skills and group processing" (p. 8), "are nearly identical to those of high-performance teams in business and industry as identified by Katzenbach and Smith (1993) where 'a team is a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable'" (as cited in Smith, et al., 2005, p. 9). Teamwork is definitely considered a very important component of working and learning together, but not all teams have successful teamwork experiences. What really matters, according to Katzenbach and Smith (1993) is the discipline that teams must share to be effective. They stated that a team's essential discipline consists of the following characteristics: "a meaningful common purpose that the team has helped shape, specific performance goals that flow from the common purpose, a mix of complementary skills, a strong commitment to how the work gets done and mutual accountability" (p. 148).

2.3.2 Importance of Instructional Support for Successful Teamwork

Establishing team discipline and providing essential principles for working together are central for supporting successful teams, but in the classroom environment require instructional scaffolding to help students navigate teamwork. In Ohland, Giurintano, Novoselich, Brackin, and Sangelkar (2015) recent work on supporting successful teams in capstone design courses in engineering, a panel discussion with the community of design educators was conducted. The main points that emerged were analyzed using Self-Determination Theory that "addresses the internalization of extrinsic motivators" (p. 1749). The results showed that for the capstone design experience to be successful, it has to start with "faculty's effort to plan for success". The authors outlined specific recommendations for instruction, showing the need for the instructor to:

"promote real world experiences, match teams and projects to empower success, teach students to work in teams, develop leadership for more effective teams, encourage regular assessment of team functioning, promote individual accountability, remediate team dysfunction, and train and monitor team mentors" (p. 1749).

An important finding from Ohland et al.'s (2015) work, that "students benefit from focused teamwork-related support throughout the capstone experience" (p. 1756), emphasizes not only the value of instructional help but also the need for knowledge of what this instructional support should be in order to help motivate students to work together successfully.

2.3.3 Communication in Teams as an Indicator of Success

Use of modern sensor technology allows opportunities to capture a lot of information about team dynamics that points teamwork research in a new direction. Pentland (2012) in "The Science of Great Teams" revolutionizes the notion of what makes teams successful through the use and analysis of sociometric data. In his study, Pentland and his team used sociometric badges to collect data on "when people are talking and their tone of voice, but not words; body position relative to others – whether people face each other and how they stand in a group; and body language, including arm and hand movements and nods, but not facial expressions" (p. 63). Looking at the collected data, researchers were able to see "highly consistent patterns of communication that are associated with productive teams, regardless of what kind of work they do. The data do not take into account the substance of communication, only the patterns, but they show that those patterns are what matter most." What Pentland (2012) found was that the most valuable way of communication is face-to-face and "the best way to build a great team is not to select individuals for their smarts or accomplishments but to learn how they communicate and to shape and guide the team so that it follows successful communication patterns" (p. 65).

Pentland (2012) also identified three aspects of communication that have an impact on team performance. The first level is energy that is measured "by the number of exchanges among team members weighted for their value by type of communication" to produce an energy score which is "averaged with other members' results to produce a team score. Energy levels within a team are not static" (p. 65). The second measure of communication is engagement, which "reflects the distribution of energy among team members" (p. 65). The third measure is exploration that "involves communication that members engage in outside their team. Exploration essentially is the energy between a team and the other teams it interacts with" (p. 65). This approach to data collection provides a more detailed explanation of what matters most for team performance and, as the results show, communication, especially face-to-face, is central to team success.

2.3.4 Looking at the Teams in the Study through a 'Teaming' Perspective

Another innovation in trying to understand successful teams and teamwork is using a 'teaming' perspective to analyze teams. Edmondson (2012) defined teaming as a "flexible teamwork" and an approach to "gather experts from far divisions and disciplines into temporary groups to tackle unexpected problems and identify emerging opportunities" (p. 75). The author notes that teaming is widespread and "it's happening now in nearly every industry and type of company" (p. 75). Teaming works well in situations that are complex and might require quick changes in direction. Different expert knowledge might be needed to solve a problem and working together with people from various disciplines is an important part of the teaming. As Edmondson (2012) stated: "Teaming is a way to get work done while figuring out how to do it better" (p. 75). In comparison to stable teams where members have a history of working together and know and understand each other's ways of working, teaming feels more like a group constantly transforming in response to challenges. Teaming requires project management and leadership that help to "plan and execute in a complex and changing environment" and to "foster collaboration in shifting groups that will be inherently prone to conflict" (p. 76). This is what the author calls the "hardware and the software of teaming" (p. 76).

For the management of technical issues or the "hardware of teaming", "leaders need to manage the technical issues of scoping out the challenge, lightly structuring the boundaries, and sorting tasks for execution" (p. 76). Some of the classic errors in hardware management as described by Edmondson (2012) include: "assuming that everything a team does has to be collaborative" and "subjecting highly uncertain initiatives to traditional project management tools that cope with complexity by dividing work into predictable phases" (p. 76). For effective teaming management, the first error can be fixed understanding that "not all tasks become team encounters" and using "input and interaction" as needed. To fix the second error, instead of following the phases such as "initiation, planning, execution, completion, and monitoring" it becomes important to make modifications in the process and "to enable execution during, rather than after learning and planning" (p. 76). Table 2-2 shows a more detailed explanation from Edmondson (2012) of the teaming hardware structure.

Table 2.2 Teaming Hardware Structure from Edmondson (2012, p. 76).

Teaming Hardware consists of scoping, structuring and sorting

Scoping

The first step in any teaming scenario is to draw a line in the (shifting) sand by scoping out the challenge, determining what expertise is needed, tapping collaborators, and outlining roles and responsibilities. When a team is already assembled, scoping includes figuring out what additional resources are needed or which team members can be freed up over time to join other groups. Successful scoping articulates the best possible current definition of the work and acknowledges that the definition will evolve along with the project.

Structuring

The second step is to offer some structure—figurative scaffolding—to help the team function effectively. Scaffolding in a teaming situation could include a list of team members that contains pertinent biographical and professional information; a shared radio frequency, chat room, or intranet; visits to teammates' facilities; or temporary shared office space. The objective of structuring is to make it easier for teaming partners to coordinate and communicate—face-to-face or virtually.

Sorting

The third step is the conscious prioritizing of tasks according to the degree of interdependence among individuals. Combining, or interdependence, can take three forms: pooled, sequential, or reciprocal.

- Pooled interdependence was the very essence of the industrial era—breaking work down into small tasks that could be done and monitored individually, without input from others. To the extent that such work exists in current projects, there's flexibility in when and where it gets done. But most tasks now require some degree of interaction among individuals or subgroups.
- Sequential interdependence characterizes tasks that need input (information, material, or both) from someone else. The assembly line is the classic example: Unless the guy upstream does his part, I cannot do mine. Teaming situations are full of these tasks; they must be scheduled carefully to avoid delays. Effective teaming streamlines handoffs between sequential tasks to avoid wasted time and miscommunication. Too often, people focus on their own part of the work and assume that if others do likewise, that will be sufficient for good performance.
- Reciprocal interdependence—work that calls for back-and-forth communication and mutual adjustment—is most critical to successful teaming. Because it's often difficult for people in cross-functional, fluid groups to reach consensus, these tasks tend to become bottlenecks. They should therefore be prioritized. It's crucial that leaders specify points when individuals or subgroups must gather—literally or virtually—to coordinate upcoming decisions and resources or to analyze and solve problems.

Table 2-3 describes important behaviors for successful teaming, such as speaking up, experimenting, reflecting, listening intently and integrating. To support behaviors for successful teaming, it's important to understand how the software should be managed and how this management process is different from traditional teamwork. It becomes essential to recognize the greater vulnerability of people in the decision-making process when working together rather than independently, and that trust built over time in stable teams is very different from trust in teaming where relationships are "constantly shifting" (Edmondson, 2012, p. 78).

> "The software of teaming asks people to get comfortable with a new way of working rather than with a new set of colleagues. This new way of working requires them to act as if they trust one another—even though they don't. Of course they don't; they don't yet know one another. Leaders have at their disposal four software tools: emphasizing purpose, building psychological safety, embracing failure, and putting conflict to work" (Edmondson, 2012, p. 78).

Table 2.3 The Behaviors of Successful Teaming from Edmondson (2012, p. 79)

Speaking Up
Communicating honestly and directly with others by asking questions, acknowledging errors, raising issues, and explaining ideas.
Experimenting
Taking an iterative approach to action that recognizes the novelty and uncertainty inherent in interactions between individuals and in the possibilities and plans they develop.
Reflecting
Observing, questioning, and discussing processes and outcomes on a consistent basis—daily, weekly, monthly—that reflects the rhythm of the work.
Listening Intently
Working hard to understand the knowledge, expertise, ideas, and opinions of others.
Integrating
Synthesizing different facts and points of view to create new possibilities.

2.4 Business 'Teaming' Meets Engineering Teamwork: Workflow Interdependence

The teaming or flexible teamwork concept can be a good lens to help think about engineering student teams used in this research study. These teams worked together during the summer semester and represented different engineering majors. This learning context situation resembles an approach to bringing "experts from far divisions and disciplines into temporary groups to tackle unexpected problems and identify emerging opportunities". Students who participated in this study were from various engineering majors and came together to work as a team only for a short period of time. This restricted them from developing a level of trust and an understanding of each other's ways of working, which is very different from the trust developed in stable teams that work together for longer periods of time.

In the literature review study by Borrego et al. (2013), social loafing behavior is identified as one of the strongest inhibitors of successful engineering students' teamwork experiences. Borrego et al. (2013) defined social loafing as "a behavior in which some team members do not contribute their fair share to the project" (p. 473). There could be various reasons for such behavior to occur in engineering teams, including time management, lack of individual work visibility, insufficient amount of time to build trust among team members, and generally poor team dynamics that influences overall performance.

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 that is "at the heart of cooperative learning" (Smith, 1996, p. 75) could be one of the ways to help teams learn to work together more effectively. Similar to the 'teaming' hardware structure identified by Edmondson (2012), where interdependence is defined as pooled, sequential and reciprocal, in engineering 'teaming' Borrego et al. (2013) described workflow interdependence as "the level of reliance one person, group, or organization has on others in order to complete a task" (p. 490) and distinguished between pooled, sequential and reciprocal, and intensive types of workflow interdependence. Table 2-4 shows descriptions for each of these levels.

Table 2.4 Levels of Workflow Interdependence in Teams of Engineering Students from Borrego et al. (2013, pp. 490-491)

Interdependence Levels In Engineering Student Teams
▪ Pooled interdependence is a form of workflow in which people or subgroups work independently, often in parallel, to achieve the organization's goal according to Tesluk, Mathieu, Zaccaro, & Marks and Thompson (as cited in Borrego et al., 2013, p. 490). A typical pooled interdependence student team would divide its assignment into discrete tasks among the members, complete tasks individually, and then combine the outputs (e.g., report sections) just before it is due. According to Van de Ven, Delbecq, & Keonig (as cited in Borrego et al., 2013, p. 490), levels of communication between the team members are low and student teams practicing pooled interdependence tend to rely heavily on the assignment specifications provided by the instructor rather than on one another. Borrego et al. (2013) state: "The design of the team assignment may unintentionally allow the students to each complete their own portion of the work with little or no coordination among members. Although engineering students often default to this efficient means of completing group assignments, this level of interdependence is unlikely to result in the types of experiences or coordination skills required for success in engineering industry teams" (p. 490).
▪ Sequential and Reciprocal interdependencies are seen when the workflow occurs in series, the output of one person or subgroup becoming the input of the next person or subgroup according to Tesluk et al. (as cited in Borrego et al., 2013, p. 490). Like a moving assembly line, sequential work flows only in one direction, with no reverse dependency as in an iterative design process according to Thompson (as cited in Borrego et al., 2013, p. 490). Borrego et al. (2013) stated: "A team using this form of interdependency would have one student begin the assignment, hand the partly completed material off to the next student to add more work, and so on, until each student had added a contribution to the assignment" (p. 490). Ito & Peterson noted that this mode of teamwork is sometimes referred to as "throwing it over the wall" to indicate the limited communication between team members as they hand off the assignment to one another and while feedback may sometimes flow "backwards," it is often too late to impact the team goals (as cited in Borrego et al., 2013, p. 490). As Tesluk et al. indicated reciprocal interdependence is similar in terms of its linear sequence, but with more feedback loops (as cited in Borrego et al., 2013, p. 490).
▪ Intensive interdependence is usually what engineering instructors envision when they assign projects to student teams (in Borrego et al., 2013, p. 491). According to Tesluk, the outputs and resources of each team member are also among the inputs of each other team member; this process occurs in a nonlinear manner (as cited in Borrego et al., 2013, p. 491). Daft noted "these teams have intense coordination among the members, who make adjustments to their individual work based on the results and knowledge of the others (as cited in Borrego et al., 2013, p. 491). Borrego et al. (2013) stated: "Feedback is much more timely and flows in all directions. In a student team, this planning is often an initial meeting to discuss logistics, communication mechanisms, and the variety of roles to be played by the team members. In addition to encouraging students to take the time up front to create these norms and roles, instructors can provide supplemental training or resources to aid students in creating infrastructure aimed at improving their ability to multidirectionally coordinate information and decisions. These resources for coordination may include meeting times and locations, project meeting and storage space, and various communication and coordination technologies, such as wikis, cloud-based collaborative spaces (e.g., Google Docs), virtual meeting spaces (e.g., Skype), and virtual team workspaces (e.g., Basecamp)" (p. 491).

As mentioned by Borrego et al. (2013), “instructor decisions and project characteristics play a significant role in students’ choices of interdependency levels.” (p. 491). Some of the teams might happen to have positive team dynamics and strong leadership (individual or distributed) that would well support team progress without necessarily needing further instructional guidance. But in reality such “well-made and performing” teams are rare, and typically instructional support is needed to help teams develop the necessary skills to get along and manage their workflow effectively. Students in engineering teams are not necessarily aware of the differences and benefits of workflow interdependence levels and they typically start with a ‘pooled’ workflow approach, dividing up tasks, working individually on their parts, then sending their results to a member in charge of assembling the pieces together into a final report the night before the assignment is due. Such way of managing team workflow does not require much communication among team members except for an initial work division and then final report assembly by a designated team member. In some cases, the work needed to complete the project might require team members to have a slightly higher level of communication than in a pooled workflow approach. Certain parts of the project need to be completed before starting work on the next parts, like working in an assembly line. Such workflow is called ‘sequential’ and requires limited communication among team members. Higher communication frequency is integral in the ‘intense’ workflow interdependence, according to Tesluk et al. (as cited in Borrego et al., 2013, p. 491), and is “usually what engineering instructors envision when they assign projects to student teams. Here, the outputs and resources of each team member are also among the inputs of each other team member; this process occurs in a nonlinear manner” (pp. 490-491).

Level of engagement and frequency of interaction among team members are the distinguishing characteristics among these workflow interdependence types. It is not surprising that the frequency and types of interactions that students engage in while working on team projects are central to successful teamwork. Going back to the Pentland's (2012) research, "the best way to build a great team is not to select individuals for their smarts or accomplishments but to learn how they communicate and to shape and guide the team so that it follows successful communication patterns" (p. 65).

In this study, eight engineering student teams worked on assigned projects throughout the summer semester and had, as a team, various opportunities to interact face-to-face as well as online. 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 teams' documents in one central location that was easily accessible from anywhere and anytime by all of the team members. In the next section Google Docs affordances for workflow management support are analyzed using Stahl's (2004) collaborative software learning criteria framework.

2.5 Google Docs Software Affordances to Support Engineering Team Workflow Management

To explore Google Docs affordances to support team workflow management, the collaborative software learning criteria framework developed by Stahl (2004) was found useful, particularly the definitions of affordances for social awareness, knowledge building and knowledge management. Framework categories are described in Table 2-5.

Table 2.5 Collaborative software learning criteria framework from Stahl (2004, p. 81)

Collaboration
Facilitating interactions, helping participants to maintain an overview of them, allowing participants to negotiate group decisions and building tacit knowing on the group level.
Social awareness
Displaying or comparing alternative interpretations of different participants in collaboration and keeping track of who knows or does what, when, where
Knowledge building
Accumulating, storing, organizing, preserving and displaying multimedia artifacts that arise in interaction.
Knowledge management
The ability to collect items from broad discourses and organize them flexibly according to various perspectives for further manipulation and sharing.
Apprenticeship
Defining tasks, activities and learning goals, simulating pedagogically meaningful experiences and monitoring progress.

Students' familiarity with Google Docs editing style made the software integration process by teams much easier. Students did not voice any concerns about usability of Google Docs, except for images and table formatting that was not as straightforward as in a Word-type document. As mentioned earlier, all eight teams used Google Docs in their work during the summer semester but it did not necessarily mean that they used it to full capacity as a work management tool in order to make their efforts more productive.

In the overview of Google Docs provided in Chapter 3, Table 3-1, Google Docs description keywords include: easy editing, anywhere and anytime access, and working on the same 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 Google Docs, social awareness is supported through the revision history feature, where “all of the changes are automatically saved” (*see* Table 3-1) and it is possible to view older revisions of the document and see who made the changes and when. 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 where team members can make Comments or post questions and clarifications about particular parts of the document, and these Comments are visible to all of the team members who can then also respond. In addition, when the Comment is posted, team members get email notifications 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 documents 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 members’ preferences. Within the documents, information can be added, deleted, edited, and/or commented on. 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.

Team awareness, knowledge building and knowledge management affordances can be used to facilitate multidirectional interaction and coordination of information among team members. More specifically, in order to help teams create a structure to facilitate the 'intensive' type of interdependence using Google Docs, team members need to increase their level of communication with each other via use of the instant chat and Comments features as well as keeping track of the revisions history to stay current with the development of the shared document. The instant chat feature is a great way for team members to interact in real time, but it has a drawback of not saving the string of interaction for later viewing or sharing with all members in the team. Posting Comments supports an asynchronous way of interaction and provides all team members with a record of interaction over time.

It is important to note that when engineering teams are starting to work on the project they should invent their own workflow process and other factors such as group dynamics, meeting scheduling conflicts and individual work patterns that can impact the team's workflow in various ways. Introducing an online tool to help students manage their workflow better can be very helpful, but without appropriate instructional support, teams might not take full advantage of the tool to really make a difference in their workflow management. Instructional recommendation and support on how to use Google Docs as a work management tool can provide students with necessary information on how to shape their workflow process to be most effective for their teams.

2.6 Why Use Technology in an Engineering Classroom?

As global engineering becomes more significant, learning how to use online technology for knowledge manipulation and organization effectively in teams of engineering students has important implications for engineering practice. According to Educating The Engineer 2020, "U.S. engineers must become global engineers. They'll have to know how to replenish their knowledge by self-motivated, self-initiated learning. They will have to be aware of socioeconomic changes and appreciate the impact of these changes on the social and economic landscape in the United States and elsewhere. The engineer of 2020 and beyond will need skills to be globally competitive…" (National

Academy of Engineering, 2005). 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.

In addition to learning how to use online knowledge management tools in student engineering teams for global engineering practice, integration of digital media in classroom culture is an important way for the instructor to connect better to the "millennial engineers" who grew up in a technology-rich environment. In the study on millennial engineers, Johri et al. (2014) found that among freshman engineers "almost all students own multiple devices, with all catering to, but not limited to, social communication, entertainment, information-seeking and learning activities" and "all of the surveyed population perform some form of multitasking" (p. 298). The authors also commented that "in our study, freshman engineering students appeared to be connected as frequently as what was described of millennials but their participation in online activities varies from person to person" (p. 298). Results of this study help to better inform engineering instructors about the “saturation of students’ lives with digital media and their use of information technology – particularly access to the Internet” (p. 298) so that they can integrate instructional design opportunities for students to use their technology experience in an educational setting.

2.7 Research Background

My original research interests were focused on developing instructional support for engineering teams to help manage workflow interdependence in online environment. What led me to focus more extensively on this topic were my initial investigations of literature in the research areas of CSCL (Computer Supported Collaborative Learning) and CoI (Community of Inquiry) during my work on Readiness Assessment and the Proposal for Dissertation Research.

Literature from the CSCL community helped me to develop a better understanding of the complexity of mechanisms underlying group learning in the online environment. The CSCL field is largely founded on the Knowledge Building philosophy developed by Scardamalia and Bereiter (2006) (as cited in Stahl, 2004, p.54) that guides interpretation of collaborative learning experiences and the goal of computer-supported collaborative learning to develop an appropriate conceptual framework and analytic perspective to begin comprehending “the subtle and complex interactions between group and individual knowing or between meaning embedded in an artifact and its interpretation in a person’s mind” (Stahl, 2004, p. 56). The process of “emergence of understandings” as a result of group work remains an open area for more research and critique in CSCL.

The importance of developing theoretical foundations for CSCL will help inform software to create effective collaborative learning environments.

Increased access to Web 2.0 tools has significantly changed our ways of teaching and learning. Affordances of web blogs, wikis, podcasting, social bookmarking and social networking sites have created opportunities for “interconnectedness, content creation and interactivity” where students can not only acquire knowledge but can also co-construct knowledge with their peers, teachers and experts in the field. It is important to keep in mind that although we rely heavily on technology to mediate our interactions, “building knowing”, especially in educational contexts, is very different in a technologically-produced environment (Stahl, 2004, p. 75) and it becomes crucial for designers of such environments to incorporate features that would effectively support the pedagogical aims of collaborative learning.

The primary focus of CSCL community research is on tool design to support collaborative knowledge building through social discourse. This focus helped support this paper’s analysis of Google Docs affordances to support team workflow but was insufficient for analyzing pedagogical implications of the software integration in engineering teams.

The Community of Inquiry framework literature review introduced me to a more comprehensive way of describing an asynchronous learning environment through the core structural elements such as cognitive, social and teaching presences. Because my original research goal was to investigate how engineering students’ co-construct knowledge in a shared document supported by Google Docs, I was interested in the application of cognitive presence theoretical perspective to the analysis of the data. As described in Garrison (2003), a “cognitive presence reflects the intellectual climate” and is “central to successful higher learning experiences”. Kanuka and Garrison (2004) further described cognitive presence as “the extent to which learners are able to construct meaning through sustained communication” and viewed cognitive presence as the “key element in critical thinking, and a necessary element for higher levels of thinking and learning” (p. 24).

To analyze students’ interaction via the Google Docs Comments feature I wanted to use the Practical Inquiry Model that is used to define cognitive presence (Garrison, Anderson, & Archer, 2000, p. 95). Within the structure of this model the following phases of inquiry were used: triggering event, exploration, integration and resolution. For each of these phases, indicators were developed and examples of coding illustrated by Akyol & Garrison (2011b, p. 185). When I started using developed indicators to identify phases of inquiry for part of my research data, student interactions captured in posted Comments, I found that the exchanges were too short for the analysis to be effective. In order for students to engage in a type of interaction that would move from a triggering event to the exploration, integration and resolution phases, online activities had to be structured by an instructor to ask students to rely more on asynchronous commenting and also to be more explicit with their Comments. In another case, students used Google Docs voluntarily and it was up to each team to invent its own style of using the tool. In summary, the Google Docs Comments feature is suitable for short interaction exchanges but does not necessarily promote extended conversations, therefore making it difficult to apply the CoI framework for analysis.

Overall, literature review of the Computer Supported Collaborative Learning and the Community of Inquiry areas of research helped to develop my understanding of the current state of the work on collaborative learning in an online environment and also helped to identify the need for application of some of the ideas from these fields to the context of engineering education. I did not find a direct application of research frameworks from either CSCL or CoI communities, because (1) the study was not about developing a collaborative tool, (2) the interaction among team members was face-to-face and online, and (3) the focus was not on knowledge building but on the workflow management that supported knowledge building. In addition, the emphasis on helping instructors to be more reflective about the tool that they introduce in their classrooms and helping students to become aware and intentional about the features of the tool is not as widely developed a topic in either the CSCL or the CoI areas of research.

As mentioned in the introduction, integrating Google Docs to support engineering students team workflow management in a naturalistic setting presented an opportunity to study ways in which students used the tool without instructional scaffolding. These conditions allowed the researcher to investigate the following **research questions**:

(1) How and to what extent do teams integrate Google Docs into their workflow?

(2) How do these integration patterns differ depending on parameters like team performance and team dynamics?

Using the results of this study, the overall research goal became building a framework for instructors about how to integrate Google Docs to better support team workflow management.

CHAPTER 3. RESEARCH DESIGN

3.1 Introduction

The purpose of this study was to explore how teams of engineering students used Google Docs during their collaborative report-writing phase and to use the analysis results to build a framework for instructors about how to integrate Google Docs to better support teams' workflow management. To build an instructional framework one must develop a deep understanding of the educational context and how the classroom "habitat" reacts to the integration of a new tool to support team workflow. To do that, it became important to collect the type of data that would help to investigate the dynamics of team workflow and also to have study design flexibility to adjust research tools to help better describe the constantly changing naturalistic setting of the classroom. The Design-Based Research (DBR) method was selected for this study as an approach to explore the dynamic of "learning ecology" (Cobb et al., 2003, p. 9), and to contribute to educational improvement by developing a theoretical understanding of the collaborative workflow processes in engineering teams.

The organization of this chapter consists of discussing the rationale for using the Design-Based Research (DBR) and an overview of this method, its limitations and how DBR fits with research goals. The research study context is described and a overview of Google Docs is provided. In addition, a research study design for each of the phases is presented with information about research goals, data sources, the data collection process and an analysis method overview.

3.2 Rationale for the Design-Based Research (DBR) Methodology

The Design-Based Research (DBR) methodology was selected to address proposed research questions in a naturalistic setting. The rationale for using DBR was rooted in this method's focus on helping "understand how, when, and why educational innovations work in practice" (Design-based Research Collective, 2003, p. 5). As mentioned in Chapter 1, one of the major motivations for this study was guided by an instructional problem in an undergraduate engineering class where the instructor wanted to help teams manage their workflow more efficiently by using online technology. Google Docs was proposed as a solution to this instructional problem. Exploring how student teams integrated Google Docs into their workflow and how these integration patterns differed depending on parameters like team performance and team dynamics in a real classroom required a more flexible research method. Such method had to capture the dynamics of intervention in practice and also had to be modified over time, based on qualitative data results to develop a better theoretical understanding of learning and teaching in a context of engineering teamwork.

3.3 Design-Based Research (DBR)

Education research in "real world" classrooms is a challenging process characterized by many variables that could influence the success of the intervention and could be difficult to control. Trying to develop an understanding of how a particular intervention would affect learning in a complex educational setting would require multiple iterations of the research experiment to improve the design over time and to provide necessary data describing the interaction of multiple variables that could influence the study results. As Collins et al. (2004) stated, "Designs in education can be more or less specific, but can never be completely specified. Evaluation of designs can only be made in terms of particular implementations, and these can vary widely depending on the participants' needs, interests, abilities, interpretations, interactions, and goals" (p. 17).

Design-Based Research experiments, as described by Collins et al. (2004), are "contextualized in educational settings, but with a focus on generalizing from those settings to guide the design process" (p. 21) and "design research assumes continuous refinement" (p. 34). Such an approach allows for a more comprehensive study of the relationship between variables that play a role in the intervention and also for integrating important elements in the new iteration of the study based on the evaluation of the previous design experiment. To have an opportunity to generalize from a study context to help guide the design process provided a powerful method to capture the dynamic of "learning ecology" and to contribute to the development of theories of learning. As Cobb et al. (2003) wrote; "Design experiments ideally result in greater understanding of learning ecology – a complex, interacting system involving multiple elements of different types and levels – by designing its elements and by anticipating how these elements function together to support learning" (p. 10).

Cobb et al. (2003) outlined distinct features of Design-Based Research experiments such as: the research process is iterative, highly interventionist, and theory-oriented with the goal of the developing theories "to do real work in practical educational contexts" (p. 12). An iterative approach to the research process allows for continuous refining of the design process and experimental testing critical to the design elements in real-life contexts. The findings from each of the phases of the design provide opportunities to reflect on the effectiveness of the intervention and how to better accomplish research goals in a given context. Highly interventionist research processes, according to Cobb et al. (2003), consider design experiments as "test-beds for innovation", stating that "the intent is to investigate the possibilities for educational improvement by bringing together new forms of learning in order to study them" (p. 10). Educational improvement is central to the design of experiments, and developing a theoretical framework that has practical implications is at the core of the design research approach. As Cobb et al. (2003) stated, "'what works'" is underpinned by a concern for 'how, when, and why' it works, and by a detailed specification of what, exactly, 'it' is. This intimate relationship between the development of theory and the improvement of instructional design for bringing about new forms of learning is a hallmark of the design experiment methodology" (p. 12).

Overall, Design-Based Research "attempts to create important, theory-based educational interventions of sizable effect and reasonable plausibility and generalizability" (Dede, 2005, p. 3). As with any research method, there are limitations that should be considered when using this methodology to design a study.

3.3.1 Limitations of Design-Based Research

"Contrary to traditional research methods," Dede (2005) wrote, "in DBR experiments many variables are deliberately and appropriately not controlled, the 'treatment' may evolve considerably over time, and the research methodologies utilized may shift to fit the morphing intervention" (p.3). In addition, the author added that "to aid with interpretation under these difficult circumstances, in DBR large quantities of datasets of various types are often collected by many participants, introducing substantial problems of alignment, coordination, and analysis" (p. 3).

The flexibility of the design methodology and its iterative nature create a complex environment for maintaining "scientific rigor" and the direction of the research. Yet the same limitations of the DBR method are its strengths that allow capturing the complex dynamic of the educational setting. A careful consideration of the potential problems with a clear identification of the overall research goals and a thorough analysis of the results from each of the study phases will allow for a design process to better approach complexities and resolve timely issues that might arise during the research progression.

In this research, limitations of the DBR methodology for the overall study design were primarily due to large amounts of data collected during each iteration of the study. When initial research design is flexible then for data collection "everything looks important" in order to capture as much as possible in a naturalistic setting (Miles et al., 2014, Chapter 2, Section 2, para. 5). Large amounts of collected data made it difficult to organize data as well as to select data for the analysis. The overall process of data management was very difficult to coordinate and was very time- consuming.

3.3.2 How Does the Design-Based Research Methodology Fit with Research Goals?

This study was exploratory in nature and aimed to look at how engineering undergraduate students integrated Google Docs to support their work process. Design-Based Research methodology fitted research design and was based on the following criteria:

The research process is iterative. Data collection started in the spring semester of 2013 with the goal of exploring general usage patterns of Google Docs by teams of undergraduate engineering students. Preliminary analysis of the data results from Phase 1 led this research to focus more on the Google Docs Comments feature and explore how students used it. For Phase 2 of the study, the researcher adjusted survey instruments by including several questions about the use of the Comments feature, and was conducted during the summer semester of 2013. Phase 3 of the data collection used the same assessment instruments as Phase 2, and was conducted during the fall semester of 2013. The goal of Phase 3 was to repeat the study design for Phase 2 and see how the results from Phase 2 and Phase 3 compared.

This research is contextualized in a real-life classroom setting. An undergraduate engineering course in a large midwestern university was used for all three phases of the research design. As part of the course structure, students worked in teams on several projects throughout the semester. To help students improve their teamwork, the instructor suggested using Google Docs to manage their workflow in an online setting. During Phase 1 of the research design the instructor did not provide any suggestions to teams on how to use Google Docs. During Phase 2 students were provided with a handout developed by the researcher that described efficient ways of using Google Docs to manage team workflow. The suggestions in this handout were based on student responses from Phase 1. During Phase 3 of the research, students were provided with an updated version of the handout that included the previous handout's suggestions about efficient usage strategies and students' Comments about their experiences using Google Docs. For all three phases of data collection, students were not required to use Google Docs. The original version of the handout can be found in Appendix A and the updated version of the handout can be found in Appendix B.

This research is practical theory-oriented with the goal of building an instructional framework about integrating Google Docs to better support team workflow management in teams of undergraduate engineering students.

3.4 Research Context

This research was influenced by collaboration with an engineering instructor in a large midwestern university who was teaching a sustainability engineering class for undergraduate engineering students. The syllabus description stated that this course "provided an introduction to the examination of global-scale resource utilization, food, energy and commodity production, population dynamics, and their ecosystem impacts". This was a normal face-to-face class where students met weekly for lectures, and teamwork was central to the structure of this course. Students worked on the same instructor-assigned teams throughout the semester, on projects related to the topics of food, water, energy and sustainability. For each of the projects the instructor provided the teams with a brief description of the problem related to the mentioned content topics, followed by open-ended questions that teams were required to answer in a form of a written report. Typically, the duration for each of the projects was three weeks during the fall and spring semesters and about two weeks during a summer semester when the schedule was more condensed.

Originally, the instructor was concerned about the management of the teams' report writing process. In prior semesters of this course, many of the teams' report writing process lacked transparency in showing individual efforts to the instructor and other team members. Frequently students relied on the "typical" model where one of the team members would be responsible for putting individual contributions together the night before the submission was due, rather then working as a team on co-constructing the report over time. In addition to the problem of tracking individual contributions, students kept bringing up the issue of the difficulty of finding time to meet face-to-face as a team due to their busy school schedules throughout the semester.

To help address the issues of team' workflow management, use of Google Docs was suggested as a way to more efficiently support report co-writing. For example, the history of edits feature could help students become more aware of the overall team's progress as well as individual team members' contributions. The co-editing feature could better facilitate co-construction of the team's report over time instead of "putting individual parts together" the night before the reports were due. The anytime-and-anywhere access by team members to the shared online workspace could help support more frequent interaction with the document.

To investigate how students integrated Google Docs into their workflow and what they thought about it, data was collected from the spring, summer and fall 2013 semesters of an engineering sustainability course. For primary data analysis, data from the summer 2013 semester was used. A total of eight teams consisting of four students each was used. All of the students enrolled in the summer class majored in various engineering degrees in the university. Five of eight teams consisted of all-male students and three remaining teams consisted of two female and two male students. The reason for selecting this data set was because the Phase 1 study explored generally how students integrated Google Docs, but Phase 2 had a more focused study design to explore how teams used the

Comments feature. In addition, all eight teams in Phase 2 used Google Docs throughout the summer semester.

As mentioned earlier, the course instructor provided students with assignments on global resources utilization, and students were expected to work in teams. To conduct their research, at the beginning of the semester each of the teams had to select a pair of developing and developed cities and then use the selected pair to work on a quantitative analysis of resources utilization (such as food, water and energy) as well as to propose management strategies for more sustainable solutions. On average, collaborative projects required one to one-and-a-half weeks to complete during the summer semester. Project results had to be presented in a written report format, and all of the team members were given the same grade for the report.

During the spring, summer and fall 2013 semesters the instructor suggested that the students use Google Docs software as a supporting collaborative tool for work outside of the classroom. Students were not required to use this software and there were no grade penalties for not using it. Throughout the summer 2013 semester all eight teams in the sustainability engineering course used Google Docs voluntarily to support their workflow process.

3.4.1 Software Selection

During the selection process for the collaborative online platform, Wiki software was considered first. Wiki software provides students with a shared online space where they can collaboratively write a document. What also made Wiki software more appealing is the fact that it was embedded in the course Blackboard platform so the students and instructor could easily access it. The instructor tested the Wiki software with his class during the spring 2013 semester, but after the first assignment, many of the students expressed their concerns about continuing to use Wiki because of the difficulties with HTML style formatting of their documents. The instructor shared these concerns with the researcher, and we came to the conclusion that Google Docs software should be used instead because of greater student familiarity with its Word style formatting options. Similarly to Wiki software, work in Google Docs could be done asynchronously or synchronously using a shared online document that everybody had access to and could see any changes made to the original document. Table 3-1 shows a summary of Google Docs features as advertised by Google on https://www.google.com/docs/about/

Table 3.1 Google Docs Summary of Features from https://www.google.com/docs/about

More than letters and words
- 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.

Get to your documents anywhere, anytime.
- Access, create, and edit your documents wherever you go – from your phone, or computer.

Do more, together.
- With Google Docs, everyone can work together in the same document at the same time
- Share with anyone. Click share and let anyone – friends, classmates, co-workers, family – view, comment on or edit your document.
- Edit in real time. When someone is editing your document, you can see as they make changes or highlight text.
- Chat and Comment. Chat with others directly inside any document or add a Comment with "+" their email address and they'll get a notification.

Never hit "save" again.
- All your changes are automatically saved as you type. You can even use revision history to see old versions of the same document, sorted by date and who made the change.

Works with Word
- Open and edit Microsoft Word files
- Convert Word files to Google Docs and vice versa
- Don't worry about buying software again

Offline? No problem.
- You can get to your documents from wherever you are, even without a signal. Simply enable offline editing to work in your browser or pin files on your mobile devices.
- Do more with add-ons.
- Take your Docs experience even further with add-ons.

Get started now.
- Docs is ready to go when you are. Simply create a document through your browser or download the app for your mobile.

3.5 Research Study Design Overview

The overall research design consisted of three phases – Phase 1, Phase 2, and Phase 3. In this section, research goals, data sources, and the data collection process are described for each of the phases. Information about the data analysis method and discussion of results for each of the phases are presented in the next chapter.

For the data collection process during all research phases a Purdue University Institutional Review Board (IRB) application was submitted. The IRB granted "exempt" status for this study. The status was granted on 6 March 2013, and the IRB protocol number is 1303013349. A copy of the IRB letter can be found in Appendix C. An additional application for and amendment to the approved study was submitted to the IRB in order to get permission to conduct an interview with the instructor of the classes where the data was collected during Phase 1, Phase 2, and Phase 3 of the research. The IRB granted an amendment exemption on 3 August 2015, and a copy of the IRB letter can be found in Appendix H.

3.5.1 Phase 1 Overview

Research goals for Phase 1 were to explore how teams of undergraduate engineering students integrated Google Docs to support their workflow in an online environment and to refine data collection and analysis methods to be used in Phases 2 and 3 of the research. Phase 1 of the research was conducted during the spring 2013 semester.

Data collected during Phase 1 of the study consisted of shared teams' Google Doc reports for an Energy project, Baseline Survey student responses, Reflection Survey 1 responses and Reflection Survey 2 responses. Descriptions of the Baseline Survey and

Reflection Surveys 1 and 2 are provided in Table 3-2. Reflection Surveys 1 and 2 included the same questions during Phase 1. Reflection Survey 1 was administered during Week 8 of the spring semester and Reflection Survey 2 during Week 16 of the semester. The purpose of the Reflection Surveys was to gain insight about students' perceptions on how well they thought their teams managed working in an online environment during the Water and Energy projects.

Table 3.2 Evaluation Instruments Used during Phase 1 of the Research

Baseline Survey The Baseline Survey was developed with the goal to collect basic demographic information about students such as their age, major and their experience level with working collaboratively in teams in face-to-face settings as well as in an online environment; their attitudes about collaboration and also their experience using Internet technologies such as Google Docs, Wikis, Blogs, Skype and Group ME Texting for personal communication, university classes or workspace (if applicable). The Baseline Survey consists of 10 questions in total, comprised of Likert scale and open-ended types of questions. This survey was administered in the beginning of the spring 2013 semester. The course instructor provided students with a web address for the Baseline Survey and students completed it online during the first week of the summer semester. A sample of the Baseline Survey can be found in Appendix E.
Reflection Surveys 1 and 2 Reflection Surveys 1 and 2 were developed with the goal to collect information for each of the participating teams about the frequency of face-to-face meetings, the use of online tools to support asynchronous collaboration, the tasks that online tools such as Google Docs were used for, and whether the use of collaborative online software was helpful or not in supporting teams' design process. Information about any additional technologies the teams used was also collected. In addition, students were asked to rate how well their teams managed some of the teamwork aspects, such as time, goal setting and work planning, communication, idea-sharing, problem-solving and conflict management. Students were prompted with open-ended questions to reflect on some of the things their teams did to increase the potential for success and to discuss some of the possible weaknesses in their teams. A Reflection Survey sample for Phase 1 can be found in Appendix F. Results from the Reflection Surveys were used to inform students' work with Google Docs software and to gain a better understanding of individual student perceptions about their experiences using online shared documents to support their team workflow.

Table 3-3 provides information about when each of the data sets was collected, how the data collection process was administered and how many students participated in the data collection. All of the surveys were administered using Purdue's Qualtrics Survey system. The researcher provided the instructor 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 Baseline Survey from the instructor in the beginning of the semester and completed it online at the time convenient to them during Weeks 4 and 5. Students completed Reflection Survey 1 during Week 8 and Reflection Survey 2 during Week 16 of the semester.

During the spring semester there were 20 teams total. There were five students per team. Only two of the teams had four students per team. Out of the 20 teams, 16 teams used Google Docs to support their workflow and co-write project reports throughout the semester. The results of the Phase 1 Google Docs use by teams were initially explored during May 2013 with the goal of providing feedback for Phase 2 of the research.

Table 3.3 Phase 1 Data Collection Process. (*Survey responses numbers are from Purdue Qualtrics*)

Data Collected	When Data Was Collected During Spring 2013 semester	Participation Rate	How Data Was Collected
Google Docs	Throughout the semester and mainly focused on Weeks 15 and 16	16 teams	Online shared Google Docs
Baseline Survey	Weeks 4 and 5	60 students	Qualtrics Online Survey
Reflection Survey 1	Week 8	85 students	Qualtrics Online Survey
Reflection Survey 2	Week 16	105 students	Qualtrics Online Survey

As mentioned earlier, the research goals for Phase 1 consisted of exploring how teams of undergraduate engineering students integrated Google Docs to support their workflow in an online environment and also to refine data collection and analysis methods to be used in Phases 2 and 3 of the research. Data that was analyzed during

Phase 1 consisted of student interactions posted in Comments and selected open-ended questions from Reflection Survey 2. Discussion of the analysis method and results are presented in the next chapter.

3.5.2 Phase 2 Overview

The goal of Phase 2 was to continue exploring the use of Google Docs by teams of undergraduate engineering students to support their workflow in an online environment and in particular to explore how teams used the Google Docs Comments feature and what affordance this feature offered. Phase 2 of the research was conducted during the spring 2013 semester.

Phase 2 was selected as the main focus for data analysis for the purpose of dissertation writing due to more manageable sample size and higher usability rates of Google Docs by participating teams as compared to data collected during the spring and fall semesters.

During Phase 2 of the study, all eight teams in the summer course used Google Docs voluntarily to support their team workflow management. The instructor gave students a handout with suggestions on more efficient ways to use Google Docs. This handout was developed by the researcher to emphasize the importance of using the Comments feature and also included some of the student responses from Phase 1 of the research on ways to use Google Docs more efficiently. This version of the handout can be found in Appendix B.

Data collected during Phase 2 consisted of authentic teams' Google Docs, Modified Baseline Survey and Modified Reflection Surveys 1 and 2. Overview of Baseline Survey and Modified Reflection Surveys 1 and 2 is shown in Table 3-4.

Table 3.4 Evaluation Instruments Used during Phase 2 of the Research

Modified Baseline Survey Baseline survey was developed with the goal to collect basic demographic information about students such as their age, major and their experience level with working collaboratively in teams in face-to-face settings as well as online environment; their attitudes about collaboration and also their experience using Internet technologies, such as Google Docs, Wikis, Blogs, Skype and Group ME Texting for personal communication, university classes or workspace if applicable. Baseline Survey for Phase 2 was modified from the version that was used in Phase 1. A question about students experience working in the field of engineering was added. One of the questions about collaboration was changed from 'responding to statements' format to a multiple choice format. In addition, a question about experience working in online environment was expanded to include additional statements that students had to respond to. Several questions from the original Baseline Survey about engineering design reasoning were removed as the focus of Phase 2 was more on the use of Google Docs by teams. Modified Baseline Survey consists of 12 questions in total, comprised of Likert scale and open-ended types of questions. This survey was administered in the beginning of summer 2013 semester. The instructor of the course provided students with a web address for the Baseline survey location and students completed it online during the first week of the summer semester. A sample of Modified Baseline survey can be found in Appendix E.
Modified Reflection Surveys 1 and 2 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. The first iteration of the Reflection Survey did not include questions about the use of the Comments feature in Google Docs. Several questions about Comments were added to the Modified version of the Reflection Survey based on the preliminary findings from Phase 1 of the research. Modified Reflection Surveys 1 and 2 are the identical in content. Modified Reflection Survey 1 was administered online after teams completed working on the Water project. Modified Reflection Survey 2 was administered online after teams completed working on the Energy project. A sample of Modified Reflection Survey can be found in Appendix G.

Table 3-5 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. All of the surveys were administered using Purdue's Qualtrics Survey system. The researcher provided the instructor 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 Modified Baseline survey from the instructor in the beginning of the semester and completed it online during week 1 Students completed Modified Reflection Survey 1 during weeks 4 and 5 and Modified Reflection Survey 2 during weeks 7 and 8 of the semester.

During summer semester there were 8 teams in total. All 8 teams had 4 students per team. All 8 teams used Google Docs to support their workflow and co-write project reports throughout the semester.

Table 3.5 Phase 2 Data Collection Process. (*Survey responses numbers are from Purdue Qualtrics*)

Data Collected	When Data Was Collected During Summer 2013 semester	Participation Rate	How Data Was Collected
Google Docs	Throughout the semester and mainly focused on Weeks 6 and 7	8 teams	Online shared Google Docs
Modified Baseline Survey	Week 1	38 students	Qualtrics Online Survey
Modified Reflection Survey 1	Weeks 4 and 5	33 students	Qualtrics Online Survey
Modified Reflection Survey 2	Weeks 7 and 8	37 students	Qualtrics Online Survey

Phase 2 was selected as the main focus for the data analysis for the purpose of dissertation writing. The research goals for this phase consisted of: continuing to explore the use of Google Docs by teams of undergraduate engineering students to support their workflow in an online environment, to explore how teams use the Comments feature in Google Docs and what affordance this feature offers, and to answer research questions such as how and to what extent teams integrate Google Docs in their workflow and how do these integration patterns differ depending on parameters like teams' performance and teams' dynamics? To do that, data that was analyzed during Phase 2 consisted of Google Docs Usage statistics, student interactions posted in Comments, as well as selected responses to open-ended and ratings types of questions from Reflection Surveys 1 and 2. Discussion of the analysis method and results are presented in the next chapter.

3.5.3 Phase 3 Overview

The goal of Phase 3 analysis was to compare selected results to Phase 2 analysis results and validate whether the original problem presented by the instructor about the management of report writing process by teams, was resolved? Because Phase 2 was selected as the main focus for the data analysis for this study, only partial data from Phase 3 was analyzed to see if students used Google Docs during Fall 2013 semester and what were their reflections about the usefulness of the tool for their teams' workflow. In addition, an interview with the instructor for the course was conducted in the fall of 2015 to investigate if students continued using Google Docs and whether this software provided overtime an efficient solution to teams' workflow management process?

Similar to the Phase 2, to introduce Google Docs in the classroom, the instructor gave students a handout with suggestions on more efficient ways to use Google Docs. This handout was developed by the researcher to emphasize the importance of using the Comments feature and also included some of the student responses from Phase 1 of the research on ways to use Google Docs more efficiently. This version of the handout can be found in Appendix B.

Data collected during Phase 3 consisted of authentic teams shared Google Docs, Modified Baseline Survey, and Modified Reflection Surveys 1 and 2. Overview of Baseline Survey and Modified Reflection Surveys 1 and 2 is shown in Table 3-6.

Table 3.6 Evaluation Instruments Used during Phase 3 of the Research

Modified Baseline Survey
Baseline survey was developed with the goal to collect basic demographic information about students such as their age, major and their experience level with working collaboratively in teams in face-to-face settings as well as online environment; their attitudes about collaboration and also their experience using Internet technologies, such as Google Docs, Wikis, Blogs, Skype and Group ME Texting for personal communication, university classes or workspace if applicable.
Baseline Survey for Phase 2 was modified from the version that was used in Phase 1. A question about students experience working in the field of engineering was added. One of the questions about collaboration was changed from 'responding to statements' format to a multiple choice format. In addition, a question about experience working in online environment was expanded to include additional statements that students had to respond to. Several questions from the original Baseline Survey about engineering design reasoning were removed as the focus of Phase 2 was more on the use of Google Docs by teams.
Modified Baseline Survey consists of 12 questions in total, comprised of Likert scale and open-ended types of questions. This survey was administered in the beginning of summer 2013 semester. The instructor of the course provided students with a web address for the Baseline survey location and students completed it online during the first week of the summer semester. A sample of Modified Baseline survey can be found in Appendix E.

Modified Reflection Surveys 1 and 2
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.
The first iteration of the Reflection Survey did not include questions about the use of the Comments feature in Google Docs. Several questions about Comments were added to the Modified version of the Reflection Survey based on the preliminary findings from Phase 1 of the research.
Modified Reflection Surveys 1 and 2 are the identical in content. Modified Reflection Survey 1 was administered online after teams completed working on the Water project. Modified Reflection Survey 2 was administered online after teams completed working on the Energy project. A sample of Modified Reflection Survey can be found in Appendix G.

Semi-Structured Interview Protocol
1. What was the original motivation(s) for you to use Google Docs software in your class?
2. How did you introduce Google Docs to students? Did you provide them with any supplemental instructional materials?
3. Did the use of Google Docs by teams in the class help to address your original motivation(s)?
4. Do you remember any critique or positive feedback from students about the use of Google Docs?
5. Do you have any critique or positive feedback about the use of Google Docs by teams in your class?
6. Do you think that use of Google Docs by teams had any impact on team dynamics and if so, in what way?
7. Are you continuing to use Google Docs in your classes? What instructional support you think would be useful for you, as an instructor as well as for your students?

Table 3-7 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. All of the surveys were administered using Purdue University Qualtrics Survey system. The researcher provided the instructor 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 were provided the link to the Modified Baseline survey by the instructor in the beginning of the semester and completed it online during week 1. Students completed Modified Reflection Survey 1 during week 8 and Modified Reflection Survey 2 during weeks 15 and 16 of the semester.

Table 3-8 provides information about an interview with the instructor that was conducted during the 2015 fall semester.

Table 3.7 Phase 3 Data Collection Process. *(Survey responses numbers are from Qualtrics)*

Data Collected	When Data Was Collected During Summer 2013 semester	Participation Rate	How Data Was Collected
Google Docs	Week 12	15 teams	Online shared Google Docs
Modified Baseline Survey	Week 1	99 students	Qualtrics Online Survey
Modified Reflection Survey 1	Week 8	72 students	Qualtrics Online Survey
Modified Reflection Survey 2	Weeks 15 and 16	76 students	Qualtrics Online Survey

Table 3.8 Phase 3 Data Collection Process For Semi-Structured Interview

Semi-Structured Interview
Interview was conducted during the Fall 2015 semester with the instructor of the class. Interview protocol was used to guide the discussion. The interview was not recorded and the researcher took notes during the interview.

To investigate if students used Google Docs during Phase 3 of the research, data that was analyzed consisted of selected student responses to open-ended types of questions from Reflection Surveys 1 and 2. Responses to open-ended questions from the semi-structured interview were used as well. Discussion of the analysis method and results are presented in the next chapter.

3.6 Summary

To address research questions that guided the exploration of Google Docs integration by engineering teams, Design-Based Research (DBR) method was used. This method was found appropriate because it allowed exploring how the proposed solution – use of Google Docs – helped teams to manage their workflows more efficiently in real life engineering classroom setting. To better capture the dynamics of naturalistic setting the study consisted of three phases. The focus of Phase 1 was to explore how teams used Google Docs to support their workflows and also to refine data collection and analysis methods to be used in Phases 2 and 3 of the research. Findings about how teams used Google Docs led to focusing more on the use of the Comments feature in Google Docs during Phase 2 of the research. The goals of Phase 2 were to answer the research questions of how and to what extent do teams integrate Google Docs in their workflow and how do these integration patterns differ depending on teams' performance and teams' dynamics. Phase 3 of the research helped to validate the findings in Phase 2 and also provide a long-term reflection about use of Google Docs for workflow support from instructor's perspective. Iterations of the study allowed to investigate "educational innovation" overtime in a naturalistic setting and to improve the focus and design of the study through feedback from each of the research phases. In the next chapter, methods used to analyze the data collected for each of the phases will be discussed as well as how the results for each of the iterations helped to answer research questions.

CHAPTER 4. DATA ANALYSIS AND RESULTS DISCUSSION

4.1 Introduction

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 for each of the phases consisted of quantitative and qualitative types. More specifically, teams' Google Docs data consisted of the history of revisions-quantitative data and interactions posted in Comments – qualitative data. Similarly, Reflection Surveys 1 and 2 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).

First Cycle methods focus on initial coding of data processes where a general inventory of data is constructed, and Second Cycle methods focus on “classifying, prioritizing, integrating, synthesizing, abstracting, and theory building” approaches (Saldana, 2010, Chapter 3, The Coding Cycles, para. 3).

During the data display activity, Excel spreadsheet software was used to organize and manipulate condensed data in order to investigate any emerging patterns. The work on the data display and conclusions drawing/verification activities of the analysis process was iterative.

The structure of this chapter consists of the data analysis overview and results discussion for each of the phases. Phase 1 is discussed in section 4.2, Phase 2 is discussed in section 4.3, and Phase 3 is in section 4.4. Section 4.5 provides a summary of the findings.

4.2 Data Analysis: Phase 1

Research goals for Phase 1 consisted of exploring how teams of undergraduate engineering students integrated Google Docs to support their workflow in an online environment and refining data collection and analysis methods used in Phases 2 and 3 of the research. To answer the question of how teams of engineering students used Google Docs in this way, students’ short interactions were posted in the Comments feature of Google Docs and their open-ended responses to the Reflection Survey 2 question (about whether Google docs software was or was not helpful in supporting their team’s work process) were used for analysis.

As mentioned earlier, First Cycle and Second Cycle methods were used for open coding during the data condensation activity. For the First Cycle method, Descriptive Coding was selected because it allowed for a “wide variety of data forms” (Saldana, 2010, Chapter 3, para 3) and assisted with initial exploratory research goals to help investigate what the focus of the study should be. Further exploration of the data was continued with Focused Coding as part of the Second Cycle method. Focused coding was deemed appropriate at this stage as it helped to develop “the most salient categories” on the data corpus and “requires decisions about which initial codes make the most analytic sense” (Charmaz, 2006, pp. 46, 57, *as cited* in Saldana, 2010, Focused Coding, para. 1). It also allowed the researcher to “develop categories without distracted attention at this time to their properties and dimensions” (Saldana, 2010, Focused Coding, para 3).

4.2.1 First Cycle Analysis: Descriptive Coding of Google Docs Comments Results

Table 4-1 shows an example of the Descriptive Coding method applied to the subset of shared online documents in Google Docs related to the teams’ use of the Comments feature. Each of the Comments (a brief online asynchronous interaction between students) was assigned a descriptive code and a subcode to better specify the meaning. For example, Comment 1 in Table 4.1 has a code “CITATION” and a subcode “Add”, meaning that the exchange that took place was about a title that needed to be added. Similarly, Comment 3 has a code “CONTENT” and a subcode “Clarification”, meaning that the goal of the Comment was to clarify some part of the content in the document.

Table 4.1 First Cycle Method: Application of Descriptive Coding to the Comments Data Results from Google Docs Shared Online Documents

Comment 1 – CITATION – Add

User 3
12:30 PM Mar 31•Re-open
Selected text:
(18.4%)
cite which numbers come from which source. All sources must be in MLA format
User 5 *Marked as resolved*
9:54 PM Mar 31

Comment 2: CONTENT - Clarification

User 3
3:44 PM Mar 31•Re-open
Selected text:
Greenhouse Gas Emissions
I am not sure what your equations are showing now that I look at them again. I am going to look on instructor's slide. Any help would be great.
User 1 they arent about emissions so idk what you mean
7:11 PM Mar 31 (edited 7:12 PM Mar 31)
User 3 *Marked as resolved*
11:37 AM Apr 1

Comment 3: SUGGESTION – To the team

User 3
12:48 PM Mar 31•Re-open
Selected text:
Energy Needs Projection
We should add a little bit about technological growth in the country. As there is more access to technology energy needs may rise in the residential and commercial settings. If you don't think it is necessary than don't add anything.
User 1 *Marked as resolved*
1:09 PM Apr 3

Comment 4: CONTENT - Change

User 1
11:03 PM Mar 31•Re-open
Selected text:
respectively
the data is inconsistent with the source
User 1 and units
11:03 PM Mar 31
User 4 *Marked as resolved*
10:27 AM Apr 1

Table 4.1 Continued

Comment 5 – CONTENT – Discussion

User 3
12:17 PM Mar 31•Re-open
Selected text:
This is a 30% increase in population from 2010. With added renewable energy sources it is assumed the energy demand will grow by 25%.
Residential
Commercial
Industrial
Transportation
2050 projected demand
(106 kWhr)
55000
45000
73750
57500
Show all
All of this needs to be more supported. What energy sources will be integrated? How has technology changed the need for energy consumption. Maybe talk about a movement to low powered computational devices. How they may affect energy use? How higher mpg cars may affect it? Make sure your assumption is not a linear growth rate.

> **User 5** Ill separate the transportation and include mpg etc to change for less demand. Will lower energy for computational provide a significant change? Seems to be a bit of a stretch. With the pop growth around 3%, it is hard to justify any other growth rates and their time periods.□
> 12:32 PM Mar 31
> **User 3** I guess my point is more that people now consume way more energy at home than they did 40 years ago. That trend will probably continue so it would be good to add something that talks about commercial and residential increase in use.□
> 1:06 PM Mar 31
> **User 5** *Marked as resolved*□
> 9:59 PM Mar 31

Comment 6 – REMINDER – To the team

User 3
12:32 PM Mar 31•Re-open
Selected text:
Current Energy Consumption
Remember to add big picture statements at the end of each section. I realize they don't ask for it and it may look like they only want facts, but they actually want opinions about the facts more than the facts.

> **User 5** *Marked as resolved*□
> 10:08 PM Mar 31

Comment 7 – UNITS - Change

User 1
10:46 PM Mar 31
Selected text:
kWhr
needs to be in J

4.2.2 Second Cycle Data Analysis: Focused Coding of Google Docs Comments Results

To develop categories of the codes generated in the First Cycle of coding, the Focused Coding method was used. As suggested by Saldana (2010) "data similarly coded were clustered together and reviewed to create tentative category names with an emphasis on process" (Focused Coding, para. 3). The data was clustered together based on the following similarities:

Comments related to editing of the document:

Comment 1 – CITATION - Add

Comment 7 – UNITS - Change

Comments related to the discussion of the content in the document:

Comment 2: CONTENT - Clarification

Comment 4: CONTENT - Change

Comment 5: CONTENT - Discussion

Comments related to the general announcements to the team:

Comment 3: SUGGESTION – To the team

Comment 6: REMINDER – To the team

Based on this organization, the following three categories emerged: Basic Editing, Content Clarification/Challenges, Organization and Suggestions. Results from the Baseline Survey and Reflection Surveys were used to supplement the findings from the Descriptive and Focused Coding methods. The following section shows an example of data analysis methods used for Reflection Survey results. Reflection Surveys 1 and 2 in Phase 2 were modified based on results from Phase 1. Several questions related to students' use of the Comments feature were added. Samples of modified versions of Reflection Survey (Energy Project) for Phase 2 can be found in Appendix G.

4.2.3 First Cycle Analysis: Descriptive Coding of Reflection Survey Results

Similar to the analysis of the Google Docs Comments feature, analysis of the results from the Reflection Surveys was done using the Descriptive Coding method during the First Cycle and Focused Coding method during the Second Cycle.

Table 4-2 shows an example of an application of the Descriptive Coding method to the results from the Reflection Survey for the Energy Project. Quotes used for analysis in Table 3.6 are student responses to the question about whether Google Docs software was or was not helpful in supporting their team's design process. Each of the quotes was assigned a descriptive code and a subcode to better specify the meaning. For example, Quote 2 has SCHEDULE-Flexibility and WORKING-Transparency, where SCHEDULE and WORKING are codes and flexibility and transparency are subcodes, meaning that the schedule was flexible and the work was transparent. Similarly, Comment 10 has a code FORMATTING and a subcode Problems, meaning that they had problems with formatting options.

Table 4.2 First Cycle Method: Application of the Descriptive Coding Method to the Results from the Reflection Survey for the Energy Project. Quotes presented are responses by students to the question about whether Google Docs software was or was not helpful in supporting their team's design process.

Student Responses	Descriptive Code
Quote 1 We didn't have to leave the comfort of our own homes. Also, we could work on it by ourselves at any time of our convenience.	SCHEDULE – Flexibility WORKING – From home WORKING – at own pace
Quote 2 It helped us to be able to work each other's busy schedules. We were able to see everyone's thoughts and ideas.	SCHEDULE – Flexibility WORKING –Transparency
Quote 3 It allowed us to work as a team without meeting as a team.	WORKING-As Team
Quote 4 Let us work on our own time and kept all of the information together and easily accessible	WORKING-At own pace INFORMATION-Organized DOCUMENT-Easy Access
Quote 5 We used Google Docs, which was very helpful considering our group members had such conflicting schedules. In class we would assign each member with a responsibility and then we would all contribute our responsibility in the Google document. We could also make notes to other team members indicating questions or areas of concern so the remaining group members could stay updated on what needed to be worked on or if anyone needed help with a certain task.	SCHEDULE-Flexibility DOCUMENT-Interactive WORK PROCESS-Staying Updated
Quote 6 The only problem that arose was because all our work was available to each member, changes were being made on each other's parts from other team members - without permission.	EDITS-Without Permission
Quote 7 Sometimes things were not clear because the team was not together to explain things directly and minor miscommunications happened.	COMMUNICATION-Not clear
Quote 8 If we are not in the same room, it can be hard to share ideas effectively.	COMMUNICATION-Difficult to share ideas
Quote 9 Sometimes there was a bit of disconnect between the different parts of the reports. The flow wasn't right.	DOCUMENT-Disconnect between parts WORK FLOW-Difficult to maintain
Quote 10 Google Docs is great for writing papers, however our report required a lot of graphs and figures which are hard to incorporate and edit in Google Docs.	FORMATTING – Problems

4.2.4 Second Cycle Data Analysis: Focused Coding of Reflection Survey Results

Preliminary analysis of the results from the Reflection Survey was continued with a Second Cycle of coding using the Focused Coding method. The data was clustered together based on the following similarities:

Quotes related to Work Process Support:

Quote 1

SCHEDULE-Flexibility

WORKING-From home

WORKING-At own pace

Quote 2

SCHEDULE-Flexibility

WORKING-Transparency

Quote 3

WORKING-As Team

Quote 4

WORKING-At own pace

Quote 5

SCHEDULE-Flexibility

WORK PROCESS-Staying Updated

Quote 9

WORK FLOW – Difficult to maintain

Quotes related to Interaction:

Among Team members

Quote 6

EDITS-Without Permission

Quote 7

COMMUNICATION-Not clear

Quote 8

COMMUNICATION-Difficult to share ideas

With a Document

Quote 4

INFORMATION-Organized

DOCUMENT-Easy Access

Quote 5

DOCUMENT-Interactive

Quote 9

DOCUMENT-Disconnect between parts

Quote 10

FORMATTING-Problems

Based on this organization, the following categories emerged: Work Process Support and Interaction, where the Interaction category consisted of interactions among team members and with the shared Google document.

Reflection Surveys 1 and 2 used in Phase 2 were modified based on the results from Phase 1. Several questions related to students' use of the Comments feature were added. The Reflection Survey sample for Phase 2 can be found in Appendix G.

4.3 Results Discussion for Phase 1

During Phase 1 of the Study Design, the goal was to explore how undergraduate engineering students used Google Docs software to support their online workflow while writing their team's reports. Google Docs shared documents for each of the teams participating in the study were shared with the researcher for review. In addition, data was collected from the Baseline Survey and Reflection Surveys 1 and 2. The Baseline Survey was administered during Weeks 4 and 5, Reflection Survey 1 during Week 8, and Reflection Survey 2 during Week 16.

Two cycles of data analysis were used for the data from Google Docs and Reflection Survey 2 (administered after teams completed the work on Energy Project). Google Docs online records showed work done by students during the time of their team projects. These records presented information about what types of contributions each of the team members made and also the timeline of these contributions. For the preliminary analysis of these Google Docs records, the subset of data that was selected for analysis focused on the use of the Comments feature by one of the teams. The primary reason for selecting this data subset was due to the emerging idea about the use of the Comments as an effective way to support students' interaction in an online environment. Descriptive Coding was used to analyze the Comments feature in Google Docs, and also for the results of the Reflection Survey 2 for the Energy Project during the First Cycle of Analysis. During the Second Cycle of Analysis, the Focused Coding method was used for both of these data sets.

Three categories were identified during the preliminary analysis of the Comments data results from Google Docs. These categories included: Basic Editing, Content

Clarification/Challenges, Organization and Suggestions. Preliminary analysis of the student responses to the Reflection Survey 2 question (administered after teams completed their work on Energy project) about whether or not Google Docs software was helpful in supporting their team's design process resulted in the following categories: Work Process Support and Interaction, where the Interaction category consisted of interactions among team members and interactions with the shared Google document.

During Phase 1 of the research study all of the students were encouraged to use Google Docs software to support their team's workflow but none of the teams were required to use it. It is important to mention that students did not receive any of the information or encouragement about using the Google Docs Comments feature. The investigation of the results showed later that two of the teams used the Comments feature to support their work and that these two teams had an anecdotal correlation between their use of Comments while working on a particular project and an increase in their teams' performance for that project. Leaving Comments that are visible to all of the team members could allow for better transparency of individual and group thinking processes and better overall coherency of a collaboratively developed artifact – the team's project report.

As illustrated at the end of this paragraph, many of the students who used Google Docs during Phase 1 of the study discussed in open-ended responses to survey questions the Google Docs affordances for their collaborative work. These affordances allowed individual team members to have more flexibility with their schedules, work at their own pace and from anywhere. As many of the students mentioned, such flexibility allowed them to continue moving the collaborative project work forward without the necessity of meeting face-to-face. Below are examples of several such student quotes about Google Docs:

> "…it allowed us to work at our own pace and saved us the difficulty of finding a time where we could all meet each other."
>
> "It allowed us to work as a team without meeting as a team."
>
> "…It gave us access to the project and enabled us to collaborate at all times rather than just a few meeting hours."
>
> "…We were able to see everyone's thoughts and ideas."
>
> "We could also make notes to other team members indicating questions or areas of concern so the remaining group members could stay updated on what needed to be worked on or if anyone needed help with a certain task."
>
> "Let us work on our own time and kept all of the information together and easily accessible."
>
> "We could all see what each other was writing at any given moment. This was helpful because it allowed us to talk to each other while on the document at the same time and to read each other's sections and reference each other's sections. Plus, it helps to ensure that everyone is doing their work because the history of the document is recorded."
>
> "…it was more convenient and practical since we didn't have to meet face-to-face every time we wanted to collaborate."

Some of the student responses pointed out the problems associated with using Google Docs software for online collaboration. These problems related to with difficulties of communicating individual ideas to the team, of understanding what other team members were trying to explain in a document, of making changes to parts of the document without asking permission of the person who wrote it, and of problems with formatting graphics and images. Below are several of the quotes from student responses:

> "The only problem that arose was because all our work was available to each member, changes were being made on each other's parts from other team members - without permission."
>
> "It was difficult to make every portion of the document flow together, because we only had the ability to write individual portions. It was thus hard to make changes to someone else's contributions without offending them."
>
> "If we are not in the same room, it can be hard to share ideas effectively."
>
> "Not meeting face-to-face sometimes creates confusion as a result of a breakdown in communication."
>
> "Sometimes there was a bit of disconnect between the different parts of the reports. The flow wasn't right."
>
> "When someone is lost it is hard to communicate since writing is limited in explaining. Talking face-to-face is easier in communicating."
>
> "Google Docs is great for writing papers, however our report required a lot of graphs and figures which are hard to incorporate and edit in Google Docs."

Student responses about the affordances of working collaboratively in an online environment related primarily to Google Docs affordances which make it an effective work management tool providing students with opportunities to have flexible schedules and work anytime and anywhere. Responses about shortcomings of working collaboratively in an online environment pointed to the importance of effective communication in order to maintain a coherent and continuous workflow.

Phase 1 of the research helped to refine data collection and analysis methods. Results analysis from Phase 1 relating to the use of Comments by teams enabled the researcher(s) to change the design in Phases 2 and 3 of the research. Several questions about the effect of using Comments on individual and teams' levels of awareness were included in Modified Reflection Surveys 1 and 2. In addition, a framework of relationships between cognitive and social group awareness was used in Phase 2 for analysis of Comments used by teams.

4.4 Data Analysis: Phase 2

Phase 2 was selected as the main focus for data analysis for the purpose of writing this dissertation writing. The research goals for this phase consisted of continuing to explore the use of Google Docs by teams of undergraduate engineering students to support their workflow in an online environment, to explore how teams used the Comments feature in Google Docs and what affordances this feature offers, and to answer research questions such as how and to what extent teams integrated Google Docs in their workflow and how did these integration patterns differ depending on parameters like team performance and team dynamics?

Data types used for Phase 2 analysis consisted of teams' Google Docs and student responses to Modified Reflection Surveys 1 and 2. Google Docs data was analyzed and consisted of the History of Revisions and Comments posted by team members. Data analyzed from Modified Reflection Surveys 1 and 2 consisted of selected questions about team management, team improvements and team weaknesses, teams' perceptions about Google Docs, teams' awareness and use of the Comments feature.

Similarly to Phase 1, the analysis process in Phase 2 followed Miles et al.'s (2014) construct consisting of "data condensation, data display, and conclusions drawing/verification" activities (Chapter 1, Section 7, para. 1). 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). Condensed data was organized and manipulated using Excel spreadsheet software. The process of conclusions drawing/verification was an iterative activity done concurrently with data display activity.

Data analysis for Phase 2 section includes an overview of Google Docs usage statistics, Google Docs Comments use and Comments types analysis, and analysis of selected questions from Modified Reflection Surveys 1 and 2.

4.4.1 Google Docs Usage Statistics

Google Docs supports the Revision History feature that shows all of the changes that were made to a shared document over a period of time. It also allows viewing and reverting back to earlier versions of the document and seeing who made what edits and when they were made. Revision History has two modes of displaying data – grouped and more detailed. To make it easier to see the "slight differences between previous document versions" revisions are grouped into short time periods. More detailed revisions option helps "to see more fine-grained revisions" to the document as shown on Google Docs help page from https://support.google.com/docs/answer/190843?hl=en

The researcher used the More Detailed Revisions option to count the instances of edits made to the document. See Table 4-3 with a sample of Revision History in Google Docs. For each of the teams, the number of 1-, 2-, 3-, and 4-member edits was counted and recorded for the Energy Project report shared document.

As mentioned earlier, all of the eight teams in Phase 2 of the research used Google Docs to support their workflow. For the data presentation and analysis, Team 53's results were excluded because of the incomplete participation in responding to Modified Reflection Survey 2. In addition, for the results presented in Row 1 of Table 4-3, all of the teams were ranked (from the lowest to the highest performing) based on their median scores for the semester and not only for the Energy Project performance.

Product Quality shown in Row 2 of Table 4-3 presents results of the evaluation of the Energy Project reports by the instructor. These results were grouped into categories based on the scores out of 100 points used by the instructor. The decision for the selected ranges was made by the researcher based on the overall spread of the results that students received. These ranges consist of the following:

Low (58=<L<62)

Low-Med (62<=LM<70)

Med (70=<M<74)

Med-High (74=<MH<80)

High (H>=80)

Ranges for the overall numbers of edits for the Energy Project reports by teams were established by the researcher based on the overall results spread. These ranges consist of the following:

Low (L<150)

Low-Med (150=<LM<250)

Med (250=<M<450)

High (450=<H<750)

Very High (>=750)

Multiple member contributions percentage values were grouped into the categories by the researcher based on the overall spread of the results. These categories consist of the following:

Low (L<25%)

Med (25=<M< 41%)

High (41=<H<50%)

Very High (VH>=50%)

Table 4.3 Results for Evaluation by the Instructor of the Energy Project Reports (Product Quality), Overall Counts of Edits for the Shared Energy Project Report, and Counts of Edits for Multiple-Member (2-, 3-, and 4-Member) Edits

(Synchronous Interaction with the Document)

Teams	15	35	25	75	65	45	55
Product Quality	L	M	M-H	H	M-H	H	H
Overall Contributions to the Energy Project Report	H	L-M	H	H	M	L	VH
Multiple member contributions to the Energy Project Report	H	M	VH	VH	M	M	H

4.4.2 Google Docs Comments Use Analysis

The Comments feature in Google Docs allows the posting of Comments directly into files “to ask questions, make notes, or highlight changes”. Posted Comments can be edited or deleted. In addition replies can be added to Comments.

(From: https://support.google.com/docs/answer/65129?hl=en)

4.4.2.1 Comments Use Frequency by Teams

Only four out of eight teams used Comments in Google Docs throughout the semester, and the quantity of Comments for the Energy Unit was insufficient (17 Comments posted) for the analysis. Throughout the semester these teams posted 41 Comments. Because the analysis of the Comments was focused more on interactional patterns, a decision was made to use all of the Comments that teams used throughout the semester and not only the ones used while working on the Energy Unit report. The counts for Comments were grouped into the Low, Medium, High and Very High categories established by the researcher based on the overall results spread. These categories consist of the following:

Low (L < 5)

Med (5= < M < = 10)

High (H > = 11)

Very High (VH > = 15)

4.4.2.2 Comments Unit of Analysis

A unit of analysis for Comments included the following types of postings: a Comment made by only one of the team members, a Comment made by one of the team members and responded to by another team member, and a Comment that contained a string of interaction between several team members. For a Comment containing multiple posts by different team members to be considered a unit of analysis, the focus of conversation had to be on the same content topic. Team 55 had a Comment that included 17 posts total and the content that was discussed in this interaction changed several times. The 17 posts in the Comment were subdivided into five units of analysis based on the content discussed. Table 4-4 shows results for the frequency of Comments use for Teams 15, 25, 45, and 55.

Table 4.4 Results for Evaluation by the Instructor of the Energy Unit Reports (Product Quality), Overall Counts of Edits for the Shared Energy Project Report, and Counts of Edits for Multiple-Member (2-, 3-, and 4-Member) Edits (Synchronous Interaction), and Use of Comments Counts (Asynchronous Interaction)

Teams	15	35	25	75	65	45	55
Product Quality	L	M	M-H	H	M-H	H	H
Overall Contributions to the Energy Project Report	H	L-M	H	H	M	L	VH
Multiple member contributions to the Energy Project report (synchronous interaction)	H	M	VH	VH	M	M	H
Use of comments (asynchronous interaction)	N/A	M	H	N/A	N/A	M	VH

4.4.3 Google Docs Comments Use First Cycle and Second Cycle Data Analysis

Similar to the Phase 1 analysis process, the Comments analysis consisted of First Cycle and Second Cycle methods, as suggested by Saldana (2010, Chapter 3, The Coding Cycles, para. 2). The First Cycle method included initial coding of data processes, where a general inventory of data was constructed. During the Second Cycle method the focus was on the "classifying, prioritizing, integrating, synthesizing, abstracting, and theory building" approaches. (The Coding Cycles, para. 3)

During the First Cycle method, student interactions posted in Comments were categorized as belonging to either content space (C) and/or relational space (R), as described in Janssen and Bodemer's (2013) framework of relationships between cognitive and social group awareness (p. 52). According to Janssen et al. (2013), the goal of interaction in the content space "is to acquire a deeper understanding of the knowledge domain associated with the collaborative task" and the goal of interaction in the relational space "is aimed at reaching shared understanding about concepts under discussion in the content space" (p. 41). The results of the First Cycle method for Teams 35, 25, 45, and 55 only had three coded Comments that were both Content Space and Relational Space types. At that point, the researcher was not sure if the Relational Type Comments should be classified further or excluded from the data.

During the Second Cycle method each of the coded Comments in the First Cycle were classified based on the type of content discussed, such as C1 (General Formatting: units correction, checking citations), C2 (Basic Content Clarification: suggestion to change some parts of the text, making a correction), or C3 (Content Clarification/Negotiation: more involved interaction among team members to resolve a question related to the content). In addition, the Comments that were coded as Relational were classified in the Second Cycle based on the tone of the interaction. The subcodes for Relational Space Comments included R1 (negative Comments), R2 (neutral Comments), and R3 (positive Comments). As mentioned earlier, only three Comments were coded as both Content type and Relational type. Two of these Comments had negative tone and one was neutral. Because there were no Comments that were coded as only Relational type and it was difficult to capture the whole tone of the conversation, it was decided not to use Relational type coded for the three Comments but to code them as content type only.

Examples of selected Comments coded during the First Cycle and the Second Cycle methods are shown in Table 4-5.

Table 4.5 Samples of Coded Comments during the First Cycle Method and the Second Cycle Method

Comment Sample	First Cycle Coding	Second Cycle Coding
Member 1 11:44 AM Jul 1, 2013•Re-open Selected text: annually Change to metric Reply Member 1 Marked as resolved 5:29 PM Jul 2, 2013	C (Content Space)	C1 (Units correction)
Member 1 7:23 PM Jul 15, 2013•Re-open Selected text: The alarming rate of resource extraction will lead to faster depletion and according to an estimate the coal, natural gas and petroleum reserves would not last more than 100 years. Show all Needs Citation Reply Member 1 Marked as resolved 7:27 PM Jul 15, 2013	C (Content Space)	C1 (Citation)

Table 4.5 Continued

Member 1 12:42 PM Jul 22, 2013 Selected text: sources We have a consensus for some of this though, right? Reply • Resolve Member 4 I added a consensus section at the bottom. We can add to it as we get more information.¶ 12:54 PM Jul 22, 2013 Member 5 I think we shouldn't use the average instead just pick one source and use it?¶ 7:13 PM Jul 22, 2013 Member 1 I agree, we need to use the most recent data¶ 8:06 PM Jul 22, 2013	C (Content Space)	C2
Member 1 11:06 PM Jul 28, 2013 Selected text: propose anyone have any other innovation ideas for decreasing water use? Reply • Resolve Member 2 a policy maybe?¶ 11:07 PM Jul 28, 2013 Member 3 water meter monitor. Lets say, if we regular residency from using more than a certain percentage of water, the water price going up twice¶ 11:07 PM Jul 28, 2013 Member 2 giant humidifier at each house?¶ 11:09 PM Jul 28, 2013 (edited 11:09 PM Jul 28, 2013) Member 2 Just like electricity we could generate water at our house¶ 11:10 PM Jul 28, 2013 Member 1 does anyone know how air conditioners work? Could those be used in a similar way to produce water?¶ 11:15 PM Jul 28, 2013	C (Content Space)	C3

4.4.4 First Cycle and Second Cycle Data Analysis for Selected Questions from Modified Reflection Surveys 1 and 2

Modified Reflection Surveys 1 and 2 included a question that asked students to rate how well they thought their teams managed in categories such as time, setting goals and work planning, decision making, communication face-to-face and communication with technology, ideas and opinions sharing, problem-solving and conflict management. Students were provided with - options such as very good, good, fair and poor.

The primary focus for - Phase 2 data analysis was the Energy Project and it became important for the researcher to see not just students' responses to the team management question for Modified Reflection Surveys 1 or 2, but to look at the trends from Surveys 1 to Survey 2. In addition, Modified Reflection Survey 1 was administered during weeks 4 and 5 of the semester and Modified Reflection Survey 2 was administered during weeks 7 and 8, and teams worked on the Energy Project during weeks 6 and 7. Looking at the trend in responses to team management question helped to see if students' perceptions changed, in what categories they changed, and also whether the trend was positive, negative or there was no change.

4.4.4.1 Team Management Trends

Modified Reflection Surveys 1 and 2 included the following set of questions shown in Figure 4-1 related to team management:

Q20: Please rate how well you think your team managed

Time	Very good	Good	Fair	Poor
Setting goals and Work planning	Very good	Good	Fair	Poor
Decision making	Very good	Good	Fair	Poor
Communication (face-to-face)	Very good	Good	Fair	Poor
Communication (with technology support)	Very good	Good	Fair	Poor
Ideas and Opinions sharing	Very good	Good	Fair	Poor
Problem-solving	Very good	Good	Fair	Poor
Conflict	Very good	Good	Fair	Poor

Q21: What were some of the things your team did to increase the potential for success?

Q22: What were some of the weaknesses in your team?

Figure 4.1 Modified Reflection Surveys 1 and 2 Team Management Questions

To evaluate the results for team management ratings question (see Question 20 in Reflection Survey 2 in Appendix G), student responses for each of the teams were counted for the categories provided and then weighted results were calculated. The answer options provided to students were weighted based on the following: 2 (very good), 1.5 (good), 1 (fair) and 0.5 (poor). Calculating the team score for each of the categories followed these steps: for each of the categories the team total was calculated. For example, in one of the teams, three students selected "good" for the time management category and one student selected "poor" as the answer. Then the totals were multiplied by the appropriate values (3*1.5 + 1*1) to produce 5.5.

Such calculations were done for each of the teams and for each of the categories listed in the team management question and also separately for the Modified Reflection Surveys 1 and 2 responses. The resulting numbers for each of the categories in Surveys 1 and 2 were compared. The difference between the numbers in each of the categories was calculated by subtracting the value in Survey 1 from the value in Survey 2. If that difference was a positive number, it was recorded as "1" and indicated a positive trend in student perceptions for a particular category. If the difference was a negative number, it was recorded as "-1" and indicated a negative trend in students' perceptions, and if the difference was equal to zero, it was recorded as "0" and indicated no change in students' perceptions. Table 4-6 shows results for calculated Team Management Trends (TMT) and also results for Product Quality (PQ) as evaluated by the instructor.

Table 4.6 Teams' Management Trends (TMT) from Survey 1 to Survey 2 Described as "-1" (Negative), "0" (No change) and "1" (Positive). Product Quality (PQ) for the Energy Project Report Described as Low (58=<L<62), Low-Med (62<=LM<70), Med (70=<M<74), Med-High (74=<MH<80), High (H>=80)

	15	35	25	75	65	45	55
PQ	L	M	M-H	H	M-H	H	H
TMT	-1	-1	1	1	1	1	1

4.4.4.2 Team Improvements and Weaknesses

In Questions 21 and 22 of Modified Reflection Surveys 1 and 2 shown in Figure 4-1, students were asked open-ended questions about what some of the improvements were that their teams used to increase the potential for success, and also what the weaknesses were in their teams.

Open coding during the data condensation process was done using the First Cycle and Second Cycle Analysis methods suggested by Saldana (2010, Chapter 3, The Coding Cycles, para. 2). During the First Cycle Method, initial coding was used to categorize open-ended students' responses. The codes used in the First Cycle Method are shown in Table 4-7. Examples from the actual responses that correspond to a particular code are included as well. Each of the examples is labeled either as "Improvement" or "Weaknesses". The Improvement label corresponds to examples of responses to Question 21: What were some of the things your team did to increase the potential for success? The Weaknesses label corresponds to examples of responses to Question 22: What were some of the weaknesses in your team?

Table 4.7 Developed Codes for Questions 21 and 22 from the Modified Reflection Survey during the First Cycle Method with Corresponding Examples from Students' Open-ended Responses

CO	Communication • Kept in contact regularly (Improvement) • We talked to each other constantly from various communication devices such as phones, face-to-face and computers (Improvement) • Didn't communicate confusion and questions early enough before some time was wasted. (Weaknesses) • We didn't communicate very well - we didn't understand the assignment or look at feedback from previous assignments (Weaknesses)
CF	Communication face-to-face • Meet face-to-face (Improvement) • Knowing the energy project was a large assignment, we met daily to work and improve on it. Having those face-to-face interactions really improved the effectiveness of our team dynamic (Improvement) • It was hard to meet up with everyone at once (Weaknesses)
CT	Communication with Technology • We adapted how we were meeting (shifting more to remote meetings than face-to-face) to accommodate people's needs. We also used the chat feature in Google Docs while people were working at the same time (Improvement) • We kept up to date with our paper through Google docs (Improvement) • We communicate through text and Google doc all the time (Improvement) • The use of the Google Doc was the best thing we could have done for a successful project. We've created templates for research logs, etc. so that we can have them on future projects (Improvement). • Communicating over Comments was sometimes frustrating due to the short, uncommunicative responses I would sometimes get, which I would have to then spend more time clarifying (Weaknesses)

Table 4.7 Continued

IC	Informal Communication • We took lunch breaks together and freely discussed non-academic issues. This helped us bond and improved our team dynamic, which enabled us to work together longer and more efficiently (Improvement) • Only meet up for class assignment. Should meet up randomly for lunch or dinner. Makes us better friends (Weaknesses)
SI	Sharing Ideas and Opinions • We respected everyone's decision and did all of our parts (Improvement) • Carefully restate ideas, plans, let everyone know why they think their own idea is important or interesting (Improvement) • We were able to express ourselves and to plan out our project (Improvement) • We discussed every problem and came up with solutions. (Improvement) • Sometimes each member had a different idea of where to go with a particular topic/idea. But eventually some kind of conclusion/consensus was reached (Weaknesses)
CM	Conflict Management • Try to resolve conflicts/questions as early as possible and start the workload as early as possible (Improvement)
PR	Peer Review • We researched different things, then checked each other's work to make sure everything made sense in the end (Improvement) • We were not able to finish our projects early to get proper feedback (Weaknesses) • Contribution of ideas and criticism lacking for the most part, and team members generally went forward with what i thought was good. Would have appreciated some positive input or even criticism, which was not very often during assignments (Weaknesses)
SG	Setting Goals • We worked almost every day after the project was assigned little by little instead of saving it for the last (Improvement) • Tried to divide roles up as evenly and fairly as possible while working to solve issues orderly and efficiently (Improvement) • Clearly delineated tasks and roles in the very beginning, to avoid confusion, conflict, unequal workloads and duplication of work. In particular, when doing research, we put all our sources in the same document to avoid wasting time searching for/reading the same sources (Improvement) • We set up a goal and achieve it during the meeting, we are productive during meetings (Improvement) • We divided up the work so we could finish the projects on time without all meeting together and we all got along that helped out the team interaction (Improvement) • Our team distributed the work based on team member's ability (Improvement) • A couple members did not understand the expectations mentioned on the rubric (Weaknesses) • Work was not done as promptly as would have made me feel comfortable; things got pushed to the late minute (Weaknesses) •

Table 4.7 Continued

PS	Problem-Solving • We could have been a little more creative with some sustainability concepts (Weaknesses) • Our team has issues conveying ideas onto paper. We are absolutely amazing at collecting every ounce of data we need the ability to talk about it has been poor (Weaknesses) • We couldn't agree on anything (ideas, script, memo) and there was poor communication and closed minds throughout the entire project (Weaknesses) • We were a little slow at getting things done and figuring out solutions to the problem (Weaknesses)
TM	Time Management • Started work on the project well in advance (Improvement) • We tried to finish projects early to get feedback. (Improvement) • We planned our meetings well. We had an agenda before the meeting so we knew exactly what we were doing when (Improvement) • We weren't able to meet up for a long time due to other's has to work (Weaknesses) • Sometimes time commitments for me and others taking other courses this summer was a hindrance to the group work meetings (Weaknesses) • Our busy schedules (Weaknesses) • Not being able to meet up. Procrastinate (Weaknesses) • Time to meet and most of us with full class schedules and work juggling each other's schedules (Weaknesses) • Time management and arrangement for team meeting was hard because some member had jobs and works (Weaknesses) • As I mentioned above, it took too much time to make a decision sometimes (Weaknesses)
CL	Collaboration • We laid out plans for completing our work and executed them. - Collaboration and using everyone's ideas (Improvement) • Made sure everyone is doing their work and giving 100% effort (Improvement) • We edited assignment together instead of leaving it to one person (Improvement)

During the Second Cycle Method suggested by Saldana (2010, Chapter 3, The Coding Cycles, para. 2) each of the codes developed in the First Cycle Method were classified as relating to the following categories: Improvements in Teams' Communication, Weaknesses Awareness in Teams' Communication, Improvements in Teams' Work Flow Management, and Weaknesses Awareness in Teams' Work Flow Management. Only responses to Questions 21 and 22 from Modified Reflection Survey 2 were used in the Second Cycle Method. Tables 4-8 and 4-9 show how the classification process was done.

Table 4.8 Second Cycle Method: Classification of the Codes as Relating to the Improvements in Teams' Communication and Weaknesses Awareness in Teams' Communication

Improvements in Teams' Communication (Question 21: What were some of the things your team did to increase the potential for success?) and Weaknesses Awareness in Teams' Communication (Question 22: What were some of the weaknesses in your team?)
CO: Communication
CF: Communication face-to-face
CT: Communication with Technology
IC: Informal Communication
SI: Sharing Ideas and Opinions
CL: Collaboration

Table 4.9 Second Cycle Method: Classification of the Codes as Relating to the Improvements in Teams' Communication and Weaknesses Awareness in Teams' Communication

Improvements in Teams Work Flow Management (Question 21: What were some of the things your team did to increase the potential for success?) and Weaknesses Awareness in Teams' Work Flow Management (Question 22: What were some of the weaknesses in your team?)
CM: Conflict Management
PR: Peer Review
SG: Setting Goals
PS: Problem Solving
TM: Time Management

Table 4-10 presents results of the Second Cycle Method. For each of the identified categories, such as Improvements in Teams' Communication, Weaknesses Awareness in Teams' Communication, Improvements in Teams' Work Flow

Management, and Weaknesses Awareness in Teams Work Flow Management, the count of codes was done and converted to magnitudes such as L (Low), M (Med), H (High) and VH (Very High) corresponding to the ranges established by the researcher based on the overall spread of the results.

Table 4.10 Results of the Second Cycle Method

Teams	15	35	25	75	65	45	55
TMT	-1	-1	1	1	1	1	1
Meeting Frequency (Energy Project)	M	H	H	L	L	M	H
Improvements in Teams' Communication (Energy Project)	M	L	H	H	L	VH	VH
Weaknesses Awareness in Teams' Communication (Energy Project)	H	H	VH	VH	H	M	M
Improvements in Teams' WFM (Energy Project)	M	H	L	M	H	VH	M
Weaknesses Awareness in Teams' WFM (Energy Project)	H	H	M	H	H	M	H

Results in Table 4-10 show that Meeting Frequency did not affect Team Management Trends from this data set and also that the Improvements Investments were higher in some of the higher-performing teams than in the lower performing teams as shown in italics for Teams 58 and 45 (low performing teams) and Teams 55 and 57 (higher performing teams) for the 'Communication' category.

4.4.4.3 Students' Perceptions about Google Docs

In Question 7 of Modified Reflection Survey (*see* Appendix G), students were asked to reflect in an open-ended type of question about their experiences using Google Docs and how it was or wasn't helpful in supporting their teams work process. The exact wording of the question used the term 'collaborative software' and not Google Docs but the student responses that were analyzed only considered the use of Google Docs.

During the First Cycle Method, initial coding was used to categorize open-ended students' responses. The developed codes used in First Cycle Method and appropriate examples from responses are shown in Table 4-11.

Table 4.11 Developed Codes for Question 7 from the Modified Reflection Survey with Examples from the Responses.

Codes	Examples
AA	Anytime/Anywhere; Schedule flexibility; Location flexibility • It was very helpful because you can work on it whenever you are free and don't have to wait for other teams • It was helpful to work together without being physically together. • It allowed us to still meet over the web so that it was still convenient for all. • It was very helpful as it allowed for full collaboration while working around scheduling conflicts and removing the need to meet face to face. • allows us to work on a single project together without getting to in the way of our daily lives. • It was very helpfully that we didn't have to work all at the same time. • It allowed us to work and communicate remotely but still in real-time. • It helped us work in our own space on our own time. • It made it easier to not meet in person but still contribute to the work. • Google docs allowed us to work at our own pace by the next time we met. • The collaborative software allowed our team to critique the material from different locations while getting others opinion.
SW	Simultaneous work; • It was helpful because we could set a time to all work on it at once instead of meeting face to face. • It allowed us to continuously work on the same document at the same time. • All members can edit simultaneously and live updated. • It was helpful in the fact that we could all be editing/adding information while talking to each other. • It was very helpful since it allowed multiple team members to communicate in real time and edit the same document simultaneously • The software let us work simultaneously on a project document while being in constant communication.

Table 4.1 Continued

WT	Work transparency; • You could also proof read what the other person is doing while they are still working. • It allowed us to see each other's thought processes and gave us the option to provide instant feedback. • It was helpful because you could see what everyone was doing as they were doing it, so it was like being in the same place • It increased work done at any time but also kept us from making sure everyone put forth the same amount of work. • Google docs allowed us to see what each team member was working on so we could work on another part. • It was great for real time collaboration on one document that could be seen and edited by everyone. This allowed us to be on the same page, provide critiques and ask questions, and piece it together all at once. • Google docs is a great way to stay connected and see other teammates' work side by side • we could see live updates and who wrote what • we could see and share the works and data • Google docs allows us to see who is doing what and put it all together easily.
CO	Communication opportunities; Collaborative writing; Co-editing; providing feedback, critique • Others can edit our ideas and contribute more • It allowed us to see each other's thought processes and gave us the option to provide instant feedback. • Group ME and google docs were especially useful as they provided an online conference room whiteboard scenarios allowing free sharing of ideas and research. • It was great for real time collaboration on one document that could be seen and edited by everyone. This allowed us to be on the same page, provide critiques and ask questions, and piece it together all at once. • The collaborative software was helpful in sharing ideas and information from our research. • The collaborative software allowed our team to critique the material from different locations while getting others opinion.

Table 4.1 Continued

WPM	Work process management; Google Document management • Google Docs helps us remotely collaborating and keeping track of others' work • Google docs was very helpful in keeping the team on track to see what has been accomplished. It made it able for our group to complete the assignment without actually meeting • It allowed us to continuously work on the same document at the same time. It increased work done at any time but also kept us from making sure everyone put forth the same amount of work. • It was helpful when we were able to distribute our projects • Google Docs helped keep things organized. • Google docs was helpful because it constantly saved our work and was a simple way to keep the document all in one place that all 4 of us could easily access. • It is awesome to have one set of documents that we can update and view in real time across all team members. It helps keep us accountable and allows us to communicate/work better. • Google docs was helpful software to organize each other's data. We uploaded all the data and findings we had, and make notes about them • Google Docs is definitely helpful in getting everyone to work on the same document at once in order to efficiently add information and finish the first draft in a timely manner. • We are able to create an outline and then follow it through to create a story and support our arguments while seeing all of the details in one place.
FP	Formatting Problems; • Google Docs wasn't user friendly regarding making tables (merging cells). The only problem was some annoying formatting errors when pasting images.
CP	Communication Problems; • we don't really "work" together. • no communication but rather just editing. • One thing that wasn't helpful was that we weren't communicating orally. • Poor at monitoring whether other members checked the updates • you didn't understand the Comment a person added to the Google doc • It would have been easier if the Google Docs chat worked.

During the Second Cycle Method, for each of the teams the count of instances of each of the codes was done and recorded for Modified Reflection Surveys 1 and 2. During the Second Cycle Method the codes used in the First Cycle Method were grouped into three categories: the first category included codes such as SW (Simultaneous

Writing), WT (Work Transparency) and CO (Communication Opportunities) to describe the collaborative nature of the Google Docs Tool; the second category included codes such as AA (Anytime/Anywhere) and WPM (Work Process Management) to describe the work flow support nature of the Google Docs Tool; and the third category included codes such as FP (Formatting Problems) and CP (Communication Problems) to describe problems that students commented on.

To answer the question "What do teams of engineering students think of the Google Docs Tool", for each of the teams in Modified Surveys 1 and 2, the total SW, WT and CO codes were counted and recorded as students' perceptions of Google Docs as a "Collaborative Tool" or as a "Work Flow Management Tool". The results of the Second Cycle Method are shown in Table 4-12. The total counts for each of the teams were converted to magnitudes such as L (Low), M (Med), H (High) and VH (Very High), corresponding to the ranges established by the researcher based on the overall spread of the results.

Table 4.12 Second Cycle Method Results Describing What Teams of Engineering Students Think of the Google Docs Tool

Teams	15	35	25	75	65	45	55
Google Docs as Coll Tool (S1 to S2)	Pos	Neg	No change VH to H	No change VH to H	No change H	No change VH to H	No change M
Google Docs as WFM Tool (S1 to S2)	No change M	Pos	Neg	N/A	Neg	Pos	No change M
Google Docs as Coll Tool (S2)	M	L	H	H	H	H	M
Google Docs as Coll Tool (S1)	N/A	H	H	VH	H	VH	M
Google Docs as WFM Tool (S2)	M	H	L	N/A	L	H	M
Google Docs as WFM Tool (S1)	M	L	M	N/A	M	L	M
Meeting frequency	M	H	H	L	L	M	H

The results in Table 4-12 show a trend in higher-performing teams of “No change” in their perception of Google Docs as a collaborative tool from Modified Reflection Survey 1 to Modified Reflection Survey 2.

4.4.4.4 Analysis of Comments Use

Modified Reflection Surveys 1 and 2 include 10 questions about the use of the Comments feature in Google Docs. These questions are in the form of ratings and open-ended types. For the analysis process, these questions were grouped into the three categories that related to the following questions: how teams used the Comments feature, how Comments supported teams’ workflow and how Comments supported teams’ awareness. Figure 4-2 shows how the questions were grouped for analysis.

How teams used Comments:

Q8: If your team used Google Docs, did your team members use the Comments feature?

Yes No Not sure what that is

Q9: If your team used the Comments feature, what were the Comments were used for?

Explain individual contributions to the document so that other team members can understand what changes you made
Ask your team members to make edits to citations, formatting, units, text
Ask your team members to clarify content by explaining the meaning of a written text, formula, etc.
Other

Q10: If you selected "other" in the previous question, please explain.

How Comments supported teams' workflow

Q15: In your opinion, was the use of the Comments feature useful in supporting your own thinking process and your team's thinking process while working on the Energy Unit? Please explain.

Q16: Would you agree that the use of the Comments feature in Google Docs helped your team to move forward more efficiently with the work?

Strongly Agree Disagree Neutral Agree Strongly Agree

Q17: Please explain your answer to the previous question.

Q12: Would you agree that the use of the Comments feature helped you to stay more connected to the project?
Strongly Agree Disagree Neutral Agree Strongly Agree

How comments supported teams' awareness

Q14: Would you agree that the use of the Comments feature in Google Docs while working on the Energy Unit helped you to be more aware about:

The thinking process of your team members Strongly Agree Disagree Neutral Agree Strongly Agree
The problems that your team members are trying to resolve

The overall team's work progress
Your own thinking process
Your own work progress

Figure 4.2 Modified Reflection Survey Questions Related to the Use of the Google Docs Comments Feature by Teams

As mentioned earlier in this section, only four out of eight teams used the Comments feature in Google Docs throughout the semester. There were 17 Comments in total posted by Teams 45, 35, 75, and 25 for the Energy Project. This quantity was insufficient for the analysis and it was decided by the researcher to use all of the Comments posted by teams in Google Docs throughout the semester (41 Comments in total for Teams 55, 65, 57 and 58). In addition, the focus of Comments use analysis was more on the interactional patterns rather than the content of those interactions.

For the analysis of Modified Reflection Surveys 1 and 2, Teams 35 and 45 were grouped into "Low-Med Google Docs Users" and Teams 25 and 55 were grouped into "High-Very High Google Docs Users". Table 4-13 shows the frequencies of Google Docs usage and the grouping of teams.

Table 4.13 Modified Reflection Survey Responses to Questions Related to the Use of the Comments Feature by Teams (Teams 35 and 45 are grouped into "Low-Med Google Docs Users" and Teams 25 and 55 are grouped into "High-Very High Google Docs Users")

Teams	35	25	45	55
Usage Frequency (Energy Project)	L-M	H	L	VH
Simultaneous Editing (Energy Project)	M	VH	M	H

4.4.4.5 How Teams Used Comments Analysis Results

Tables 4-14 and 4-15 show results for Low-to-Med Google Docs Users – Teams 35 and 45, and High-to-Very High Google Docs Users - Teams 25 and 55. These results are based on the count of responses to the question about what the Comments were used for. Responses were counted and converted to magnitudes such as L (Low), M (Med), H

(High) and VH (Very High) corresponding to the ranges established by the researcher based on the overall spread of the results.

The options for usage included in the question consisted of the following: Explain individual contributions to the document so that other team members can understand what changes you made; Ask your team members to make edits to citations, formatting, units, text; Ask your team members to clarify content by explaining the meaning of a written text, formula, etc.

Table 4.14 Modified Reflection Survey Students' Responses to Questions Related to What the Comments Feature Was Used for by Low-to-Med Google Docs User Teams

Teams	35	45
Types of Comments (all projects)	1C1 5C2(2R) 1C3	5C2 2C3
Used Comments for content clarification	M	VH
Used Comments to ask members to make edits, etc.	H	VH
Used Comments to explain individual contributions	M	M

Table 4.15 Modified Reflection Survey Students' Responses to Questions Related to What the Comments Feature was used for by High-Very High Google Docs Users Teams.

Teams	25	55
Types of Comments (all projects)	7C1 4C2	9C1 8C2(1R)
Used Comments for content clarification	VH	H (3)
Used Comments to ask members to make edits, etc.	VH	H (3)
Used Comments to explain individual contributions	H	VH

Low-to-Med Google Docs Users Teams have similar coded results for the types of Comments they used in Google Docs. The majority of the Comments were used to clarify content (C2 and C3) types of Comments. For Team 35 it was 5C21C3 and for Team 45 it was 5C22C3. Looking at how students perceived what the Comments were used for, Team 35 students indicated lower usage of Comments for “content clarification” as compared to the coded results from Google Docs. Team 45’s ratings were more consistent with the coded results. Looking at the responses to using Comments for “asking members to make edits”, Teams’ 35’s and 45’s ratings did not match with the coded results.

High-to-Very High Google Docs Users Teams have different coded results for the types of Comments they used in Google Docs. For the “content clarification” Comments, Team 25 had 4C2 and Team 55 has 8C2 results. Looking at how students perceived what the Comments were used for, Team 25 students indicated a higher usage of Comments for "content clarification” as compared to the coded results from Google Docs. Team 55’s ratings were more consistent with the coded results.

4.4.4.6 How Comments Supported Teams’ Workflow Analysis Results

Tables 4-16 and 4-17 show results for Low-to-Med Google Docs Users (Teams 35 and 45) and High-Very High Google Docs Users (Teams 25 and 55) count of responses to questions about how Comments supported teams’ workflow. Responses were counted and converted to magnitudes such as L (Low), M (Med), H (High) and VH (Very High), corresponding to the ranges established by the researcher based on the overall spread of the results.

Table 4.16 Modified Reflection Survey Students' Responses to Questions Related to How the Comments Feature Supported Teams' Workflow by Low-to-Med Google Docs User Teams

Teams	35	45
Types of Comments (all projects)	1C1 5C2(2R) 1C3	5C2 2C3
Comments supporting individual and teams' thinking process	H	VH
Would you agree that Comments helped your team to be more efficient?	H	H
Would you agree that Comments helped you to stay more connected to work?	H	VH

Table 4.17 Modified Reflection Survey Students' Responses to Questions Related to How Comments Supported Teams' Workflow by High-Very High Google Docs User Teams

Teams	25	55
Types of Comments (all projects)	1C1 5C2(2R) 1C3	5C2 2C3
Comments supporting individual and teams' thinking process	VH	VH (3)
Would you agree that Comments helped your team to be more efficient?	L	VH
Would you agree that Comments helped you to stay more connected to work?	M	VH

Results of Survey responses for the Google Docs Work Flow Support Affordances for Low-to-Med Users teams showed that students in Team 35 (higher-performing team) and Team 45 (low-performing team) agreed that the Comments feature helped them to be more efficient as a team, helped them to stay more connected to the work, and supported individual and teams' thinking process

Results of Survey responses for the Google Docs Work Flow Support Affordances for High-to-Very High Users showed that Teams 25 and 55 used Google

Docs very actively and also these teams had a higher percentage of simultaneous editing. All of the students in Team 55 (higher-performing team) agreed that the Comments feature helped them to be more efficient as a team and also helped them to stay more connected to the work. In contrast, Team 25 (low-performing team) had low agreement about Comments helping them to be more efficient, and also not all of the students agreed that Comments helped them to stay more connected to the work.

4.4.4.7 How Comments Supported Teams' Awareness Analysis Results

Tables 4-18 and 4-19 show results for Low-to-Med Google Docs User (Teams 65 and 45) and High-Very High Google Docs Users (Teams 25 and 55) count of responses to questions about how Comments supported teams' awareness about the workflow. Responses were counted and converted to magnitudes such as L (Low), M (Med), H (High) and VH (Very High), corresponding to the ranges established by the researcher based on the overall spread of the results.

Table 4.18 Modified Reflection Survey Students' Responses to Questions Related to How the Comments Feature Supported Teams' Awareness about Teams' Workflow in Low-to-Med Google Docs User Teams

Teams	35	45
Usage Frequency (Energy Project)	L-M	L
Simultaneous Editing (Energy Project)	M	M
Comments Use (all projects)	M	M
Types of Comments (all projects)	1C1 5C2(2R) 1C3	5C2 2C3
Helped to be more aware of the thinking process of your team members	M	H
Helped to be more aware of the problems your team members are trying to resolve	M	H
Helped to be more aware of the overall teams' work process	M	M
Helped to be more aware of your own thinking process	M	VH
Helped to be more aware of your own work process	M	H

Table 4.19 Modified Reflection Survey Students' Responses to Questions Related to How the Comments Feature Supported Teams' Awareness about Teams' Workflow in High-to-Very High Google Docs User Teams

Teams	25	55
Usage Frequency (Energy Project)	H	VH
Simultaneous Editing (Energy Project)	VH	H
Comments Use (all projects)	H	VH
Types of Comments (all projects)	7C1 4C2	9C1 8C2(1R)
Helped to be more aware of the thinking process of your team members	L	VH (3)
Helped to be more aware of the problems your team members are trying to resolve	H	VH (3)
Helped to be more aware of the overall teams' work process	L	H
Helped to be more aware of your own thinking process	H	H
Helped to be more aware of your own work process	M	H

Results of Survey responses for the Google Docs Teams' Awareness questions for Low-to-Med Users showed that students in Team 45 (a higher-performing team) indicated that Google Docs helped them to be more aware of: teammates' thinking processes, the problems team members were trying to solve, and their own thinking and work process in contrast to Team 35 (a low-performing team).

Results of Survey responses for High-to-Very High Users showed that students in Team 55 (a higher-performing team) indicated that Google Docs helped them to be more aware of: teammates' thinking processes, overall teams' work process, and their own work process in contrast to Team 25 (a low-performing team).

4.5 Results Discussion for Phase 2

During Phase 2 of the Study Design, the goal was to continue exploring the use of Google Docs by teams of undergraduate engineering students to support their workflow in an online environment, and in particular to explore how teams used the Comments feature in Google Docs and what affordance this feature offered. Google Docs shared documents for each of the teams participating in the study were shared with the researcher for review. In addition, data was collected from the Baseline Survey and Reflection Surveys 1 and 2 that were administered during Week 1 for the Baseline Survey, Weeks 4 and 5 for Reflection Survey 1, and Weeks 7 and 8 for Reflection Survey 2.

Data selected for the analysis of Phase 2 was focused on the Energy Unit, with the exception of the Google Docs Comments data. All eight teams used Google Docs during the summer semester. Only four out of eight teams used the Google Docs Comments feature, and the quantity of Comments for the Energy Project was insufficient for analysis. Because analysis of the Comments was focused more on the interactional patterns, a decision was made to use all of the Comments that teams used throughout the semester and not only the ones used for the Energy Project.

To answer Research Question 1 about how and to what extent teams of engineering students integrated Google Docs to support their workflow, results of the Google Docs usage analysis from seven of the eight participating teams were grouped into the following categories: Participation frequency (Level 1), Simultaneous editing (Level 2) and Asynchronous commenting (Level 3). Overall frequency of edits to the shared document varied across the teams, from a low number of edits (less than 150 edits) to high (from 450 to 750) and very high (greater than 750 edits). Out of a total frequency of contributions, synchronous interaction with the shared document was calculated for each of the teams. Synchronous interaction refers to the instances of multiple members working simultaneously on the shared document. Members working synchronously could be working on different parts of the document and their editing could range from minor formatting to a more substantial contribution to the content of the document. If in total less than 25 % of the editing was done synchronously, it was categorized as low, and if more than 50 % of the editing was done synchronously, it was categorized as very high. Asynchronous interaction among team members was captured in Comments posted by students. Only four out of eight teams used the Comments feature, so if less than five Comments were used, the team was categorized as a Low Comment user, and if more than 15 Comments were posted, then the team had a Very High usage of asynchronous interaction.

Results of this analysis for Google Docs integration were compared to the teams' performance on the Energy Project as evaluated by the instructor. The teams' dynamics were evaluated using the Team Management Survey that measured the change in teams' ratings from Reflection Survey 1 to 2 of how well their teams managed time, goals settings, communication in person and online, ideas and opinions sharing, problem-solving and conflict management categories.

4.5.1 Google Docs Integration Categories

Overall results from how actively team members contributed to the shared document (Level 1 integration) varied across the teams, and there were no indicators of dependency between Google Docs integration patterns and performance of teams on the Energy Project as evaluated by the instructor. For the frequency of using Google Docs, there were also no indicators of connection between Level 1 Integration frequency and teams' dynamics ratings from the Teams' Management Survey.

Similarly to the Level 1 Integration patterns, Level 2 Integration results varied across the teams and there were no indicators of dependency between Google Docs integration patterns and performance of teams on the Energy Project as evaluated by the instructor. For the frequency of using Google Docs there were no indicators of connection between Level 2 Integration frequency and teams' dynamics ratings from the Teams' Management Survey.

As mentioned earlier, only four out of eight teams used asynchronous interaction via the Google Docs Comments feature. Posted Comments were analyzed using the First and Second Cycle analysis methods. During the First Cycle method, interactions among students posted in Comments were categorized as belonging to either content space (C) and/or relational space (R), as described in Janssen and Bodemer's (2013) framework of relationships between cognitive and social group awareness (p. 52). During the Second Cycle method, each of the coded comments in the First Cycle was classified based on the type of content discussed, such as C1 (General Formatting: units correction, checking citations), C2 (Basic Content Clarification: suggestion to change some parts of the text, making a correction), or C3 (Content Clarification/Negotiation: more involved interaction among team members to resolve a question related to the content). Similarly to the overall frequency of usage (Level 1 Integration) and synchronous co-editing (Level 2 Integration), there were no indicators of connection between Level 3 Integration frequency and teams' dynamics ratings from the Teams' Management Survey.

To answer the Research Question 2 on how Google Docs integration patterns differed depending on parameters like teams' performance and teams' dynamics, the overall analysis results showed that Google Docs Integration Patters did not appear to associate with teams' product quality or teams' dynamics. It appeared that team dynamics was a good indicator of teams' success and the use of Google Docs (in this study) did not seem to have a noticeable impact on changing the teams' performance. The next section discusses the results of the survey responses and their comparison to teams' performance and teams' dynamics.

4.5.2 Reflection Surveys Analysis Overview

Several of the trends have emerged from the analysis of the student survey responses that highlight the differences in higher-performing teams' reflections about the use of Google Docs.

4.5.2.1 Perception of Google Docs as Collaborative Tool

Students' perceptions about Google Docs were evaluated based on the coded responses to open-ended question which asked them to reflect on their experiences using Google Docs and how it was or was not helpful in supporting their teams' work process. Some of the most common positive responses reflected the usefulness of Google Docs to support workflow from anywhere and anytime, providing transparency of work progress, having an option to work simultaneously in a shared document, better organizing the work process, and providing additional opportunities for communication among team members. Several of the students' Comments illustrate some of the positive affordances of Google Docs:

> "It was very helpful because you can work on it whenever you are free and don't have to wait for other teams."
>
> "It was very helpful as it allowed for full collaboration while working around scheduling conflicts and removing the need to meet face-to-face."

"Allows us to work on a single project together without getting to in the way of our daily lives."

"It was very helpful that we didn't have to work all at the same time."

"It allowed us to work and communicate remotely but still in real-time."

"The collaborative software allowed our team to critique the material from different locations while getting others' opinion."

Some students felt that Google Docs provided a way to stay connected to the project without necessarily needing to schedule meetings with team members to stay current with the report writing progress. Students also found the simultaneous editing of the document and the transparency of the contributions history to be useful tools for supporting their work process. Some of the comments focused on these reflections:

"It was helpful because we could set a time to all work on it at once instead of meeting face-to-face.

"It was helpful in the fact that we could all be editing/adding information while talking to each other."

"You could also proofread what the other person is doing while they are still working."

"It allowed us to see each other's thought processes and gave us the option to provide instant feedback."

"Google Docs allowed us to see what each team member was working on so we could work on another part."

"It was great for real-time collaboration on one document that could be seen and edited by everyone. This allowed us to be on the same page, provide critiques and ask questions, and piece it together all at once."

"Google Docs is a great way to stay connected and see other teammates' work side-by-side."

"Google Docs allows us to see who is doing what and put it all together easily."

Some of the student responses emphasized the importance of additional asynchronous communication opportunities that Google Docs provided for team members. As some of the Comments stated, Google Docs makes "free sharing of ideas and research" easier because it "provides critiques and questions", as well as gives quick feedback. Although text-based communication is frequently viewed as the "lean way" of interaction that cannot support the nuances of face-to-face communication such as facial cues and changes of tone present in an educational setting or during a collaborative team work activity, the use of text-based communication could be preferred when "the objective is higher-order cognitive learning" (Garrison, et al., 2000, p. 90). The authors continued supporting their argument with findings from the literature review they conducted that suggest "the reflective and explicit nature of the written word ... encourages discipline and rigor in our thinking and communication" (Garrison et al., 2000, p. 90). In other words, there is a possible connection between the use of text-based communication and supporting higher-order thinking. In a later publication, Garrison et al. (2010) continued to support their original view about the importance of text-based communication for knowledge construction in asynchronous online learning (p. 6).

Some of the student reflections focused on the problematic aspects of using Google Docs. The majority of such responses addressed either the difficulties with formatting such as “not being user-friendly when trying to ‘make tables’ or ‘paste images’”, or emphasized problems communicating with team members, stating that Google Docs did not necessarily support communication “but rather just editing”, was not clear on the “Comments the person added to the document” and did not support oral communication.

During the Second Cycle coding of the reflection surveys responses, some of the codes were grouped together to address the nature of Comments about Google Docs supporting collaboration through opportunities for simultaneous co-editing and transparency of contributions as well as opportunities for text-based communication, and Comments about Google Docs supporting more of the work process by allowing anywhere and anytime access, and workflow management. Based on this grouping of the coded responses, the results showed that higher-performing teams did not change their positive perception of Google Docs as a Collaborative Tool from Survey 1 to Survey 2. In other words, higher-performing teams perceived Google Docs more as a space for collaborative co-editing of the shared document where each other’s work and joint teams efforts were transparent and text-based interaction was a valuable tool for enhancing teamwork experience.

4.5.2.2 Teams’ Awareness Ratings

Members of the teams that used the Comments feature (Level 3 Google Docs Integration) responded to the questions asking about their experiences of interacting via using Comments. There were a total of 10 questions addressing teams’ experience using the Comments feature. These questions consisted of ratings format as well as open-ended types. For the analysis process, these questions were grouped into three categories: how teams used Comments, how Comments supported teams' workflow, and how Comments supported teams' awareness.

There were no consistent themes that emerged from the analysis of how teams used Comments, especially when comparing low-performing and higher-performing teams. Students were asked to make selections for what they used Comments for and the options provided included the following: to explain contributions to the document so that other team members could understand what changes were made; to ask your team members to make edits to citations, formatting, units and text; and to ask your team members to clarify content by explaining the meaning of a written text, formula, etc.

The actual Comments that each of the teams posted were coded by the researcher as C1, C2 or C3 type of Comments, where C1 is General Formatting (units correction, checking citations), C2 is Basic Content Clarification (suggestions to change some parts of the text, making a correction); and C3 (Content Clarification/Negotiation (more involved interaction among team members to resolve a question related to the content). And later the results of the coded comments were compared to how students in the teams perceived what they used the Comments for.

Low-to-Med Google Docs user teams had similar coded results for the types of Comments they used and the majority of those Comments were used to clarify content (C2 and C3 types). Student perceptions in the higher-performing team about using Comments primarily for content clarification were more consistent with the coded results in contrast to the lower-performing team where students thought they used Comments more for asking members to make edits and not so much to clarify content. Similarly, in High-to-Very High Google Docs user teams, student perceptions about using Comments for content clarification were more consistent with the coded Comments in the higher-performing team in comparison to the lower-performing team.

This slight difference in perceptions between low-performing and higher-performing teams is important to mention, but there is not enough evidence to make any claims based on these results as the sample size was small and the question of granularity is not sufficient to draw any conclusions.

In the second category, the questions asked students: to explain whether the use of the Comments feature was useful in supporting their own thinking process and their team's thinking processes while working on the Energy Project, to rate and explain the answer to whether using the Comments feature in Google Docs helped their team to move forward with the work more efficiently, and to rate whether the use of the Comments feature helped each student to stay more connected to the project.

Students' responses in Low-Med Google Docs users group showed similar results for low- and higher-performing teams where team members agreed that the Comments feature helped them to be more efficient as a team, to stay more connected to the work, and supported their individual and teams' thinking process.

Results of Survey responses for the Google Docs Work Flow Support Affordances for High-to-Very High Users showed that all of the students in the higher-performing team agreed that the Comments feature helped them to be more efficient as a team and also helped them to stay more connected to the work. In contrast, in the low-performing team agreement was low about Comments helping them to be more efficient and also not all of the students agreed that Comments helped them to stay more connected to the work.

Overall, the difference in students' responses to whether the use of the Comments feature was helpful for supporting their workflow is apparent in the active Google Docs users group, where the higher-performing team thought that Google Docs helped to support efficiency of their teamwork. In the lower-performing Google Docs users group, both higher- and low-performing teams found Google Docs useful in supporting the thinking process, being more efficient as a team, and staying more connected to the work. Such results, although insufficient for making claims due to the small sample size, point to an important suggestion that for the less active Google Docs users, regardless of their performance level, using asynchronous communication such as Comments is a very important tool to enhance overall teamwork coordination and to help team members stay current with the workflow.

In the third category, the questions asked students to provide ratings for whether the use of the Google Docs Comments feature while working on the Energy Unit helped team members to be more aware of the thinking process of the team members, the problems that team members were trying to resolve, the overall team's work progress, and their own individual thinking process and individual work progress.

The results of the analysis of student responses showed that overall, the higher-performing groups in both Low-to-Med and High-to-Very High Google Docs Users had higher ratings in this category of questions related to teams' awareness. More specifically, students in Team 45 (higher-performing team) in the Low-to-Med Google Docs Users group indicated that Google Docs helped them to be more aware about the thinking process of teammates, the problems team members were trying to solve, and their own thinking and work process in contrast to Team 35 (low-performing team. Students in Team 55 (higher-performing team) in the High-Very High Google Docs Users group indicated that Google Docs helped them to be more aware about the thinking process of teammates, the overall teams' work process, and their own work process in contrast to Team 25 (low-performing team).

Going back to the original coding of Comments posted by all four of the teams, it is worth noting that the majority of coded results showed that Comments were used by teams as a way to interact about the content being synthesized by all of the team members. The content coded Comments were subdivided into the following three subgroups: C1 (General Formatting: units correction, checking citations), C2 (Basic Content Clarification: suggestions to change some parts of the text, making a correction), and C3 (Content Clarification/Negotiation: more involved interaction among team members to resolve a question related to the content). These subcategories are part of the content space that teams engaged with actively. Janssen and Bodemer (2013) defined content space as collaborative space where students "exchange ideas and opinions, ask questions, produce arguments and counterarguments, and generally work toward producing a group product...The goal of interaction in the content space is to acquire a deeper understanding of the knowledge domain associated with the collaborative task." (p. 41).

Participating in content space interactions is an important component for teams' success in final report production, but what is even more critical is how well team members coordinated activities in the content space or the level of cognitive group awareness that they developed, defined by Janssen and Bodemer (2013) as "awareness that results from information about groups members' knowledge, or the opinions they hold, … all of which can be used to coordinate activities in the content space of collaboration" (p. 42). The authors further stated "cognitive group awareness is considered to be an important prerequisite for successful collaboration" (p. 42).

Distinguishing between participation in the content space and coordinating the content space (or having cognitive group awareness) could be used to explain why higher-performing teams in both Low-to-Med and High-to-Very High Google Docs users scored higher on the teams' awareness and self-reflection questions. It is possible to draw a connection to the difference in using the tool between low- and higher-performing teams. Low-performing teams, although participating in the content space as the coding of the Comments results showed, might not necessarily have developed a needed level of teams' awareness important for coordinating the content more efficiently. Yet higher-performing teams, in addition to participating in the content space, also paid more attention to what their team members knew and to what questions they had, and used this information to more effectively manage knowledge during the teams' report writing process.

4.5.2.3 Product Quality and Team Management Trend

Through analyzing the Team Management Trends from Modified Reflection Surveys 1 and 2, that asked students to rate how well they thought their team managed in categories such as time, setting goals and work planning, decision making, communication face-to-face and communication with technology, ideas and opinions sharing, problem solving and conflict management, and comparing these results to the instructors' evaluation of the teams' product, higher-performing teams in this study also rated their teams' management more positively when compared to the low-performing teams.

What students thought about their teams, in particular relating to organization of the work process, most likely is a reflection of their direct experiences of interacting with their team members to manage different aspects of the workflow, and could be a good indicator of how successful the team was. In addition, comparing student responses over time (from Survey 1 to Survey 2) could also reflect not only team members' interactions but also teams' shared history built over time, based on team members following through on things that they had positive interactions about.

As discussed in the Literature Review chapter, perhaps one of the ways to identify a successful team is based on its members' communication patterns. According to Pentland (2012), building a successful team "…is not to select individuals for their smarts or accomplishments but to learn how they communicate and to shape and guide the team so that it follows successful communication patterns" (p. 65).

In addition to having successful interaction patterns among team members, their shared work history could be a strong influence on the development of positive student interdependence that further contributed to a more efficient way of team members' knowledge coordination and produced a successful project report.

4.6 Data Analysis: Phase 3

The goal of Phase 3 analysis was to compare selected results to Phase 2 analysis results and validate whether the original problem presented by the instructor about the management of report writing process by teams, was resolved or not. Because Phase 2 was selected as the main focus for the data analysis for this study, only part of the data from Phase 3 was analyzed to see if students used Google Docs during the Fall 2013 semester and what their reflections were about the usefulness of the tool for their teams' workflow. In addition, an interview with the course instructor was conducted in the Fall of 2015 to investigate if students continued using Google Docs and whether this software provided over time an efficient solution to teams' workflow management process or not.

To investigate if students used Google Docs during Phase 3 of the research, analyzed data consisted of selected student responses to open-ended types of questions from Reflection Surveys 1 and 2 and results from the interview with the instructor.

4.6.1 Google Docs Usage Results

Out of total of 95 students in the class, 76 students responded to Modified Reflection Survey 2 questions. Out of 76 students, 72 (95%) of the students said that they used Google Docs for working on the Energy Project and 5% said that they used GroupMe texting software support.

Students selections of Google Docs usage showed that the majority of students used it for co-writing the final report, followed by keeping a record of literature findings, outlining work tasks/schedules, brainstorming ideas, keeping in touch with team members, recording meeting notes, and other tasks that included sharing video clips, research and collaboration, video conferencing, proofreading each other's work and then making Comments about improvements.

4.6.2 Students' Perceptions about Google Docs

Students' responses to an open-ended question asking them to reflect on their experiences using Google Docs and how it was or was not helpful in supporting their teams' work process. The exact wording of the question used the term "collaborative software"' and not Google Docs, but student responses that were analyzed only included students who said they used Google Docs.

For the analysis of student perceptions about Google Docs, codes developed during Phase 2 were used. These codes include AA (Anytime/Anywhere), SW (Simultaneous Work), WT (Work Transparency), CO (Communication Opportunities), WPM (Work Process Management), FP (Formatting Problems) and CP (Communication Problems). More detailed information about these codes with appropriate examples can be found in Table 4-11. Figure 4-3 shows the results of the coded responses. Total code count for each of the categories is shown.

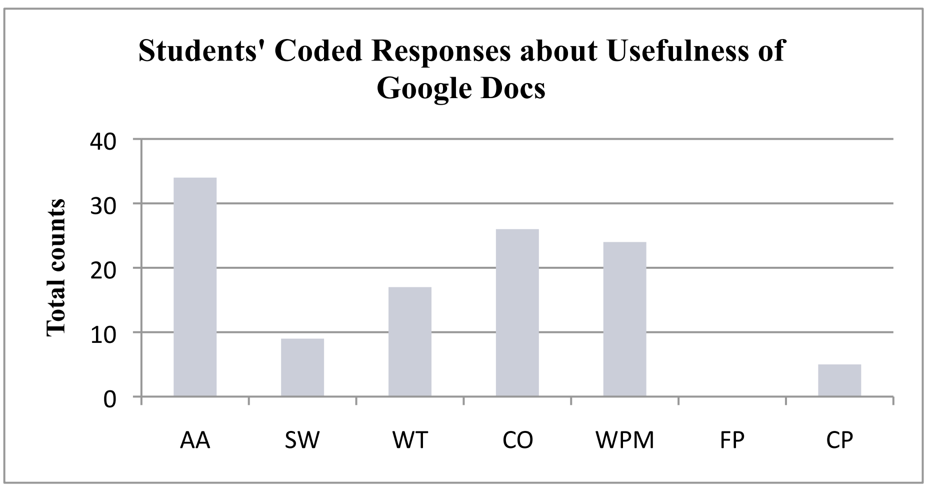


Figure 4.3 Phase 3 Data Coding Results. Total count of codes for each of the categories developed in Phase 2

4.6.3 Instructor's Reflection about Integration of Google Docs in the Classroom

During the Fall 2015 semester, a semi-structured interview with the Sustainability course instructor was conducted to obtain the instructor's reflection about the integration process of Google Docs in an engineering classroom during the spring, summer and fall

2013 semesters. The interview protocol can be found in Table 3-6. The questions included focusing on the original motivations the instructor had for using a technological solution such as Google Docs to support student teamwork, whether or not this tool helped to address the problems, and what instructional support on how to use Google Docs was provided to students. In addition, the researcher asked if the instructor continued to use Google Docs in his engineering classes.

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). During the First Cycle method, where the focus was on initial coding of data processes, Descriptive coding was used. During the Second Cycle method, Focused coding was used to categorize the results. Discussion of the themes discovered during the interview is presented in the next section.

4.7 Results Discussion for Phase 3

4.7.1 Google Docs to Support Workflow Process

72 student responses to open-ended question about whether Google Docs was or was not useful in supporting teams' work process were coded using categories developed during Phase 2 analysis. In total, the coding process resulted in 115 coded results for all of the categories.

Out of 115 Comments, 34 were coded as the Anytime/Anywhere category type. Comments made by students in this category primarily addressed the usefulness of Google Docs software in providing opportunities to work from home and also at the time convenient to students rather than trying to figure out how to meet in person as a whole team. As some of the Comments stated: "It was helpful to be able to work on the project whenever it was convenient for everyone - we didn't have to have one time where we could all meet", "Allowed us to communicate while not being face-to-face", "Allowed for the team to share ideas without meeting", and also helped "to put together project in an efficient manner". Google Docs supported teams' work on the project regardless of team members' schedules because "most of us did not have time to meet". Problems with schedule management for face-to-face meetings was a reoccurring topic in student Comments, as reflected in one student who said: "Since every member in the team is senior and has a lot going on every week, we had to utilize the online software. It turned out really nice and we did not have to waste our time trying to manage meeting hours." Another Comment stated: "The software was helpful because we all had busy schedules. It allowed for us to keep track of each other's progress, so we could help the people who were lagging or getting behind. It also gave people the flexibility to work from different locations at different times". In addition, Comments stated that Google Docs "helped us to work together even when we weren't together" and "everyone could move at their own pace and let their ideas be heard". Google Docs supported opportunities for continuous interaction with the shared document by all of the team members regardless of the location and time availability: "Google Docs was extremely helpful. We could do our individual parts, see work from other teammates, and work on the same document at the same time at different locations. This was essential to all our group projects".

Out of 115 Comments, nine Comments were coded as the "Simultaneous Work" category type. Comments in this category reflected the benefits of Google Docs in supporting work on a shared document by team members in real time. Some Comments stated that: "Google Docs real-time online collaboration was invaluable" and "It allowed us to work on the report and project at the same time and to add to each other's ideas" and see "the changes in real-time".

Opportunity for simultaneous work is a built-in feature of Google Docs that can also be supported by Instant Chat. The drawback of the Chat feature is that for now it cannot be saved and viewed later by other team members who could not participate at the time or by team members who participated in the chat and want to review what was discussed there. When Google Docs allows all of the instant chat interactions to be saved, it will be very useful information for students to support their teams' thinking process.

Seventeen out of 115 Comments were coded as "Work transparency" category types. "Work transparency" Comments were frequently a continuation of discussion of simultaneous editing by students that resulted in students being able to see each other's work progress in real time. But Comments about Google Docs's usefulness in supporting "Work transparency" also discussed the importance of monitoring each other's progress and the development of the document as a whole. Google Docs helped in "keeping track with what the others do", "it allowed us to split up the work while monitoring what other team members were doing", and "we could all work on the project whenever we had time, yet we could still see what our teammates had added and we could ask them questions", as well as "give our opinions and correct mistakes". Student Comments showed that work transparency over time was a useful way to "view the progress of the paper" and to recall how the document and teams' thinking had changed. One Comment stated: "We can look back and see what other members have written and allowed us to follow our brainstorming and what everyone had to accomplish." From student Comments it seems that Google Docs helped teams to stay current with both the individual's and teams' work progress. As one of the students noted, “ Google Docs is extremely helpful in keeping everyone on the same page about where the team is on the current project.” From students’ responses it appears that work transparency is a very important component for workflow management that is typically difficult to support in teamwork without the assistance of a software tool and extra efforts made by team members to help keep everyone updated on team progress.

Out of 115 comments, 26 were coded as the “Communication opportunities” category type. These Comments focused on Google Docs’ usefulness in supporting team member interaction via collaborative co-writing and co-editing of the shared report. “Keeping in touch with team members”, “commenting on each other’s work”, and sharing “sources of information, video clips and other documents” are just some of the examples coded as “Communication opportunities”. One of the students said: “We used Google Docs and GroupMe throughout the entire semester. Since we didn't meet outside of class, they were essential tools for us to be able to communicate 24/7.”

Some of the Comments stated that Google Docs helped teams to share, “to add to each other’s ideas”, and “to comment and ask for clarification on the spot” that possibly helped students’ “to integrate everyone’s ideas” in the final report. One of the students said that Google Docs “let their ideas be heard” which is an important statement showing the tool’s power in helping facilitate everybody’s input in report writing and helping to make students’ thinking visible. Maintaining communication throughout the work on the project is one of the most important attributes of successful teams, and although the Google Docs type of tool cannot be presented as an alternative to a face-to-face interaction, it offers a supplemental way to help team members build new ways of written interaction that are accessible to all.

Out of 115 Comments, 24 were coded as the “Work Process Management” category type that focused on Google Docs benefits in supporting overall team work flow by helping “to put all of our parts together for the final document”, as one of the students said, and was also “extremely helpful in organizing thoughts” and “outlining what needs to be done”. Different teams had different approaches to how they used Google Docs to manage their work process. One of the students commented: “We always paste the assignment requirements at the top of the document, and color code the sections so we can see what is done, what's almost done, and what needs work”. Another student said: “It is really useful to break down the work and share among group members.”

Google Docs also provided an easily accessible storage space for team members’ work and decreased the need to email the latest version of the document. One student said: “It's also nice not having to email documents and worry about which version is the most current”. Another student commented that Google Docs made it “easier to re-format the entire thing as it is all in one place”.

Ease of accessibility of the shared document and being up-to-date on the changes made to it helped to keep students current with the work process. One of the students commented: “It also helped us watch the work of our fellow students and ensure our own work was in the same tone.” It seems from student Comments that using Google Docs added flexibility to the work process yet kept them connected and current, both of which made the overall work process more effective. One student commented: “It helped us put together our project in an efficient manner.”

There were no instances of “Formatting Problems” types of Comments found in students’ reflections. This could be explained by the similarity of the Google Docs interface with Word documents. Students did not need much time to learn how to use the tool and could quickly start using it to write the report.

There were five Comments out of 115 coded as the “Communication Problems” category type. Some of the problems as described by students resulted in a decreased need to meet face-to-face, because as students said: “The only way that Google Docs hurt us was that we did not meet face-to-face as much as we would have without Google Docs” and “it limited face-to-face interaction outside of class time”.

Another problem that was revealed in student responses is how the responsibility of work completion in an online environment is not as urgent to some of the students who may feel that there is no need to complete their parts quickly because they might contribute their work later in the process. As one of the Comments stated: “Since Google Docs allowed people to work on the projects at their convenience it allowed some team members to work on it when they can, which is nice, although it also allows some people to forget about it and not start working on it…despite many reminders.” Another student said: “It can be very easy for team members to put off working on the document when there are no assigned times to work on it” and this could make “some people slack off”. Such behavior by some of the team members could be exacerbated when the use of an online environment is a main mechanism of teams’ communication, but would most likely also happen without the support of an online tool and is a result of team dynamics that needs to be addressed by the team to figure out how to manage it in both face-to-face and online environments.

Overall, out of 115 codes, 110 highlighted the positive aspects of Google Docs for teams' work process, including work process flexibility, opportunities for synchronous and asynchronous document co-writing, communication via use of Instant Chat and Comments, as well as ways of seeing individual contributions and teams' overall work progress through a record of edits of the report. In future research, it will be important to investigate how team dynamics presents itself in an online environment and to compare it to a face-to-face working environment. Online space affords many opportunities for supporting continuous workflow by helping team members have access to the document anytime and anywhere. Being able to view the most current collaborative version of the document could help motivate students to stay up-to-date with their individual work responsibilities. But it is also important to account for variability in work styles among students and to understand better how online environments can hinder or support some of these differences and what the instructor can do to help teams use the tool to their advantage.

4.7.2 Interview Responses Overview

Results of the interview with the instructor are organized based on the main discussion themes that emerged.

4.7.2.1 Motivation to Integrate Google Docs: Teams' Working Documents Organization

The researcher asked the instructor to think back to the original motivation for integrating Google Docs in to the classroom and whether or not Google Docs helped to address some of the problems. The instructor said that one of the motivations for using Google Docs was to help teams better organize their documents and have a shared online space where they could keep track of their work and have easy access to the document, and Google Docs worked well as a repository for teams to store, organize and easily access their work.

4.7.2.2 Motivation to Integrate Google Docs: Team Members' Work Transparency

The instructor also commented about the usefulness of the History of Edits feature that keeps track of all of the edits that were made to the shared document and, although not measured or visible to the instructor, from the anecdotal evidence students said it was useful to have a record of edits because they could see better what each of the team members contributed to the document over time. For the instructor these student Comments were important because they reflected a heightened level of awareness among team members, provided more transparency to the work process, and hopefully impacted positively students' level of responsibility to each other, supported better positive interdependence and decreased social loafing that is sometimes a concern in teamwork experiences.

4.7.2.3 Motivation to Integrate Google Docs: Time Management

The instructor also said that Google Docs' usefulness in helping students manage their time more efficiently made it an attractive option for the course. In addition to a lower level of interdependence, in some of the teams students tended to postpone working on the assigned project. As the instructor commented, in some teams the students would divide up the tasks and would not work on them until the night before the assignment was due. Using Google Docs helped to keep students more current with the progress so that the team as a whole made better progress writing the report and possibly were better motivated to contribute their parts more promptly so that other students could build off of each other's ideas. The added level of transparency to the report writing also positively affected how students managed their own as well as their teams' time to produce the final report.

4.7.2.4 Google Docs Support in Low-Performing Teams

Overall it seemed that Google Docs had a positive influence on how students managed their work process. At the same time the instructor said that Google Docs did not necessarily help the low-performing teams as much because the most important thing to keep in mind is that teams needed to know how to work as a team and Google Docs could not help with that. It is a very important statement because it shows from an instructor's experience that teams' dynamics is really a determining factor of a team's success, and additionally supports that the use of technology such as Google Docs cannot change the dynamics of a team much.

4.7.2.5 Google Docs to Support Workflow in Engineering Teams

The researcher also asked if Google Docs was useful for engineering teams specifically, and the instructor said that in his class where teams produce a report for each of the projects, Google Docs was very helpful. The instructor continues to use Google Docs in his classes and said that in recent semesters the students often start out using Google Docs as a default way to write a report before the instructor even introduces it to the class, and that a majority of the students continue using this tool throughout the semester even though it is not required.

4.8 Summary

To answer the research questions that guided the exploration of Google Docs integration by engineering teams, data analysis process followed Miles et al.'s (2014) suggested analysis activities (Chapter 1, Section 7, para. 1). Open coding during the data condensation process was done using the First Cycle and Second Cycle Analysis methods suggested by Saldana (2010, Chapter 3, The Coding Cycles, para. 2). Phase 1 results analysis helped to identify use of Comments as an important focus for Google Docs usage analysis for Phase 2 of the research. Results of the Phase 2 analysis helped to answer research questions. To determine how teams of engineering students integrated Google Docs to support their workflow, levels of integration were identified as Participation frequency (Level 1), Simultaneous editing (Level 2), and Asynchronous commenting (Level 3). To determine to what extent teams integrated Google Docs to support their workflow, instances of 1-, 2-, 3- and 4-member edits were counted for each of the teams (Level 1 and Level 2 integration) as well as the frequency of Comments (Level 3 integration). To answer the research question about how Google Docs integration patterns differed depending on parameters like teams' performance and teams' dynamics, the results of this analysis for Google Docs integration were compared to the teams' performance on the Energy Unit as evaluated by the instructor. Teams' dynamics were evaluated using the Team Management Survey that measured the change in teams' ratings from Reflection Survey 1 to 2 of how well their teams managed time, goals settings, communication in person and online, ideas and opinions sharing, problem-solving and conflict management categories. Overall analysis results showed that Google Docs integration patterns differed among engineering teams in a naturalistic setting and these integration patters did not appear to be associated with teams' product quality or teams' dynamics. In addition, survey student response results showed that higher-performing teams did not change their positive perception of Google Docs as a Collaborative Tool between Survey 1 to Survey 2, or have higher team awareness ratings when using Comments, or more positive team management trends than the low-performing teams evaluated through team members' self-ratings.

In addition, results of the interview conducted with the instructor in the Fall 2015 semester showed that integration of Google Docs in engineering classes helped teams to better manage their workflows through better storage and organization of documents, more efficient time management and an increased level of individual accountability. The instructor continues using Google Docs in his current classes and finds it a useful tool for helping teams manage their work process inside and outside of the classroom. But according to the instructor, it is important to realize that teams need to know how to work as a team, and just using a tool like Google Docs won't help with that. The next chapter will discuss how the data analysis findings can improve the development of an instructional framework to integrate Google Docs to better support teams' workflow management.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 How Engineering Student Teams Integrated Google Docs to Support the Workflow, What They Thought About It, and What the Instructor Thought about It

5.1.1 Google Docs Integration Levels

In this study, students primarily used Google Docs during their report-writing phase. This phase can be mapped to the knowledge synthesis stage of the engineering design process. It is important to note that the researcher did not collect data on how participating teams went about the initial planning of their work or which workflow structure they decided to use. What was found from the analysis of Google Docs usage was that integration of the software in the teams' workflow during the report-writing phase happened at multiple levels that were characterized as Participation Frequency Level, Simultaneous Editing Level, and Asynchronous Commenting Level. Table 5-1 provides descriptions for each of the Google Docs integration levels used by teams participating in the study.

Table 5.1 Google Docs Integration Levels

Google Docs Integration Levels	Patterns of Use
Participation Frequency	Teams primarily relied on Google Docs as a shared space where they contributed individual parts and also edited already written text.
Simultaneous Editing	When two or more students were working in the shared document at the same time. Although it was difficult to distinguish from the history of revisions whether simultaneous work happened on the same part of the text or team members were working simultaneously on different parts of the document, they were aware of the changes made to the document in real time.
Asynchronous Commenting	Team members commented on the shared document in order to ask questions, make suggestions or have informal conversations.

5.1.2 Google Docs Use and Reflection in Higher- and Lower-Performing Engineering Teams

As shown in Table 4-4, when the extent of Google Docs usage for each of the levels was measured and compared across teams, no similarities of integration patterns were found. Such results were also true for the comparison analysis of Google Docs integration patterns among higher- and lower-performing teams as shown in Table 4-3 and Table 4-4. From these results, it appeared that integration patterns of Google Docs to support workflow did not show a relation to teams' performance. In addition, it was found that higher-performing teams also rated their team's management more positively when compared to the self-evaluation of the lower-performing teams. These results could indicate that teams' Google Docs integration patterns do not necessarily relate to their team's dynamics as well.

Results analysis showing differences in Google Docs integration patterns can be explained by the fact that teams can be creative in inventing their own unique workflow. That could have implications on how each of the teams chose to use Google Docs to manage their work. Some of these decisions could be defined by limitations, such as Internet access or an insufficient level of proficiency with Google Docs. But other decisions could be due to individual preferences for not making individual work transparent to all team members or preferring discussing work in a face-to-face context rather than in an online environment. For future study, better understanding teams' decisions that led them to choose a particular workflow management process could be very useful data for informing analysis results of Google Docs integration patterns.

Responses from Reflection Survey 1 to Reflection Survey 2 about how students perceived their experiences using Google Docs (*see* Table 4-12) showed differences when higher- and lower-performing teams were compared. For example, higher-performing teams did not change their positive perception of Google Docs as a Collaborative Tool between Reflection Surveys 1 to 2, and rated their teams' level of awareness higher when using the Asynchronous Commenting Level. In addition, as mentioned earlier, higher-performing teams had more positive team management trends than lower-performing teams that were evaluated by measuring changes in team members' self-ratings between Reflection Surveys 1 to 2.

5.1.3 Instructor's Reflections about Google Docs Integration

Interview results with the instructor conducted in the Fall 2015 semester showed that the use of Google Docs by teams of engineering students helped them manage their workflow more effectively through better storage and organization of documents, more efficient time management, and an increased level of individual accountability. It is interesting to note that the instructor continues to use Google Docs in his current engineering classes and finds it to be a useful tool for helping teams manage their work process inside and outside of the classroom. During the interview the instructor also emphasized that in order for a team to be successful, team members need to know how to work as a team, but that a tool like Google Docs would not help with that.

The need to know how to work as a team can be related to the literature on successful teamwork discussed in Chapter 2, where according to Katzenbach and Smith (1993), what really matters for the teams to be successful is team discipline characterized by "a meaningful common purpose that the team has helped shape, specific performance goals that flow from the common purpose, a mix of complementary skills, a strong commitment to how the work gets done and mutual accountability" (p. 148). Similarly, Smith et al. (2005) define the characteristics or "essential elements" of a successful team as consisting of "positive interdependence, face-to-face interaction, individual accountability/personal responsibility, teamwork skills and group processing" (p. 94-95). Use of a workflow management tool such as Google Docs can help increase success with some of these aspects, such as individual accountability through work transparency, information processing and management through ease of access and organization of the documents, and time management by allowing team members to work anytime and anywhere. But the teams need to define their own workflow process and take leadership, individual or mutual, on how the shared goal will be achieved. Team members need motivation to develop the discipline to get things done, and frequently this motivation comes from a strong and sustained leadership. It is also important to note that, in order to establish team discipline, instructional support is needed. As research by Ohland et al. (2015) shows: “that for the capstone design experience to be successful, it has to start with ‘faculty’s effort to plan for success’” (p. 1756). Similarly, for a workflow management tool like Google Docs to be used effectively, instructional support is needed to show students how to integrate the tool. The next section describes Google Docs affordances for helping teams manage their work and also gives an instructional opportunity to help teams become aware of Google Docs benefits in managing their workflow more efficiently.

5.2 Understanding Affordances of Google Docs for Supporting Teams’ Workflow

In Chapter 2, Section 2.5, several Google Docs affordances for supporting teams’ workflows were identified using Stahl’s (2004) “Collaborative software learning criteria” framework (p. 81). These affordance included: work/knowledge management, collaborations, and social “team” awareness. Where work/knowledge management is supported through storing various formats of documents that can be easily accessed anytime and anywhere by all of the team members and also documents organization, Google Docs becomes not only a central place for the team to store documents but also to build new knowledge collaboratively. This affordance can facilitate better coordination of a team’s report-writing activities.

Collaboration affordance is supported through opportunities for interaction and co-editing. Team members co-write a document and track each other’s changes. They can also post Comments to ask questions, and to clarify or negotiate content with other team members. This affordance can facilitate better communication among team members that is essential for keeping everybody “on the same page” about the progress of the work.

Social “team” awareness is supported in Google Docs 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 when. Also, the Comments feature allows team members to post questions that will be visible to all of the team members. This affordance can better facilitate teams’ workflow interdependence through making alternative interpretations visible to everyone, and by keeping track of who knows or does what, when and where.

In Figure 5-1, connections between central elements of the Instructional Framework for Google Docs integration are shown. Affordances of Google Docs for work/knowledge management, collaboration, and social “team” awareness” are shown to more efficiently facilitate coordination, communication and interdependence in engineering teams working collaboratively in a shared online space.

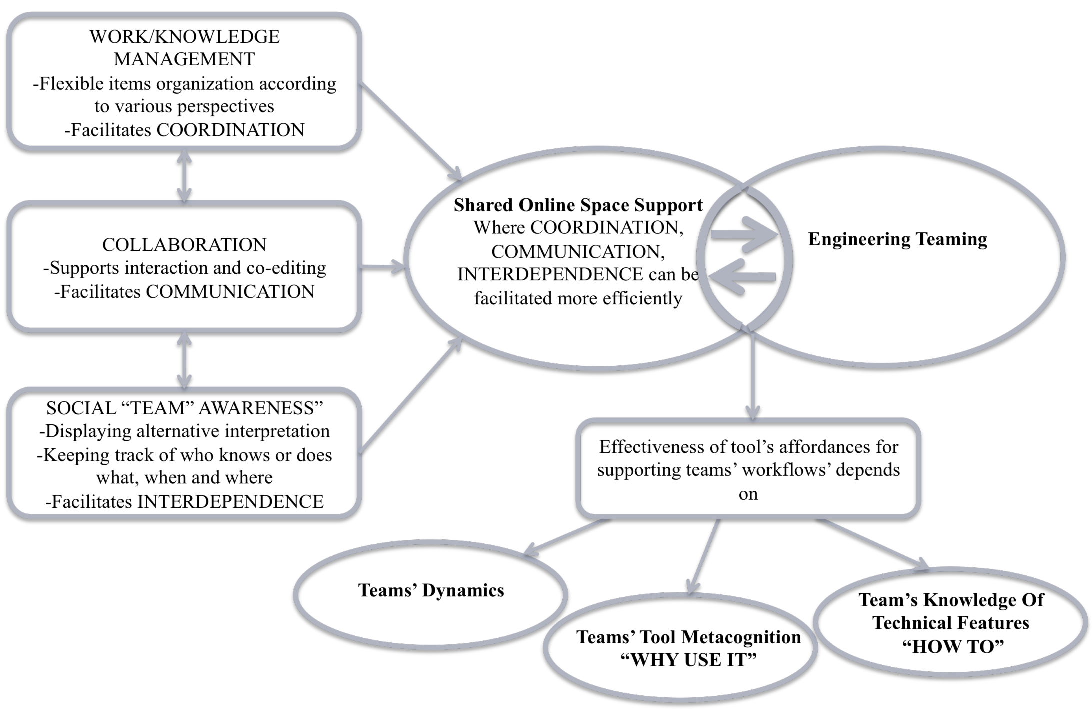


Figure 5.1 Instructional Framework for Google Docs Integration

5.3 Effective Integration of Google Docs in Engineering Teams

As Figure 5-1 illustrates, Google Docs affordances can more efficiently facilitate coordination, communication and interdependence in a shared online space. How engineering student teams interact with this shared space will determine how well the use of different affordances can support a team's workflow. This research suggests that the effectiveness of Google Doc's affordances depends on parameters such as team dynamics, team knowledge of technical "How to" features of the tool, and the team's Tool Usage Metacognition "Why Use It" knowledge of the tool.

Tool Usage Metacognition is a concept that has emerged from this research and refers to understanding why using a particular tool (for example, Google Docs in this study) would be helpful for supporting workflow management. "Why Use It" is different from "How to Use It" that refers primarily to the mechanics of using the tool to support workflow. The sample size in this study was too small to make a statement about these findings, but they can be helpful in starting the conversation about how Google Docs can be introduced to student teams in engineering classrooms and the importance of the instructor emphasizing not only "how to use" the tool but also "why use it".

Introducing an online tool to help students manage their workflow better can be very helpful, but without appropriate instructional support, teams might not take full advantage of the tool to really improve their workflow management. Instructional recommendation and support on how to use Google Docs as a work management tool can provide students with necessary information on how to shape their workflow process to be most effective for their teams.

5.3.1 Teams' Workflow Patterns and Google Docs Behaviors

In the context of engineering teaming experience, one of the important instructional goals becomes to help team members develop "positive interdependence" Smith (1996, p. 75) in their workflow. When integrating Google Docs, instructors should be aware of different teams' behaviors associated with different patterns of teams' workflow from (Borrego et al., 2013). Table 5-2 illustrates "typical" teams' behaviors when using Google Docs. For example, the Pooled or "Divide and Conquer" approach to workflow management in teams would be characterized by team members working in parallel, with low levels of communication, coordination and interdependence. In contrast, a Sequential or "Throwing it over the Wall" workflow management approach would be characterized by teams working sequentially, with limited communication, coordination, reliance on each other. A third approach, the Intensive or "Working Together" would be characterized by team members frequently interacting with each other to coordinate the work and building on each other's ideas, exhibiting a high level of interdependence.

Understanding the relationship between workflow patterns and teams' behaviors in an online environment could be a valuable tool for an instructor to use to identify "indicators of problems in teams' workflow" and to take a proactive approach in helping teams to address the problems. Table 5-2 shows examples of the relationship between teams' workflow patterns and the use of Google Docs associated with these behaviors.

Table 5.2 Teams' Workflow Patterns and use of Google Docs

Workflow Interdependence Levels (Borrego et al., 2013)	Workflow Patterns	Team's Communication Level	Team's Interdependence Level	Team's Coordination Level
Pooled "Divide and Conquer"	Parallel	Low	Low	Low
Sequential "Throwing it over the wall"	Linear	Med	Limited	Med
Intensive "Working Together"	Nonlinear	High	High	High

5.4 Practical Implications of Instructional Framework for Integration of Google Docs in Engineering Teams

Table 5-3 illustrates some practical instructional suggestions for using Google Docs to help support workflow in engineering teams based on the framework developed in this research (*see* Figure 5-1). The intent of these suggestions is to help the instructor structure the integration process more effectively and become aware of the importance of timing the introduction of Google Docs to the teams, the ways to introduce it, the importance of emphasizing the "why" as well as the "how" of using the tool, and what team behaviors to encourage when students start integrating the software into their workflow.

Table 5.3 Instructional Suggestions for Using Google Docs in Engineering Teaming (When, How and What)

When to Introduce Google Docs to Teams:

- The instructor should introduce the tool early during the work planning stages. Google Docs use should be integrated early on as part of the workflow management process for each of the teams.

How to Introduce Google Docs:

- Introduce it as a work management tool to help team members stay current with the work process, to be transparent about the overall and individual progress, and especially to be more coordinated and efficient with their work.
- Help students develop an awareness of how Google Docs can support their team's workflow.

What Teams Behaviors to Encourage for Using Google Docs Efficiently

- All team members should become familiar with Google Docs features and agree on how members will interact with each other (ways to use Chat, Comments, and co-editing the content).
- All team members should use Google Docs frequently to contribute their individual parts and to co-edit each other's work.
- All team members should agree with each other on how to co-edit each other's work (provide an explanation of changes made in a Comment so that the author of the content understands what changes were made and why they were made).
- Use the Comments feature frequently to post questions and responses.
- Check frequently for updates to the shared documents.

5.5 Next Research Steps

The overall goal is to continue developing and refining an instructional framework based on research findings about how to integrate Google Docs to better support teams' workflow management. The next research steps will be to continue exploring the interaction of the workflow support "tool" and the "team" in the context of engineering education. In particular, it will be useful to develop better understanding of concepts such as team dynamics, team interdependence, Tool Usage Metacognition and Team Awareness, as well as their connections to each other.

It will also be important to develop measures for the Tool Usage Metacognition, Team Awareness and Workflow Interdependence concepts. For example, measures for Tool Usage Metacognition would primarily consist of survey instruments and interview protocols to get students' feedback on why to use the tool. Team Awareness measures would consist of survey instruments and interview protocols to get students' reflections, as well as direct data collection from Google Docs on how frequently students co-edited the document and posted comments. Workflow Interdependence measures would consist again of survey instruments and interview protocols to learn about students' thinking, but also would include direct data collection from Google Docs to evaluate the frequency of communication in a shared document. Examples of specific follow-up research initiatives would include:

-Investigation of how students in a First Year Engineering class plan to use Google Docs to support their workflow in the beginning of the semester. The goal of this study would be to better understand through student surveys, interviews, and records of student teams' meeting notes how students think about integrating Google Docs during the initial planning stages of their project. Would some of the teams be intentional about how to use Google Docs and what it would be useful for?

-Investigation of how students in First Year Engineering class would actually integrate Google Docs during the semester and comparison of these findings to the previous study results on how students planned at the beginning of the semester to use Google Docs? Also, a comparison could be made between higher- and lower-performing teams on how the planning and integration approaches differed. Surveys and interviews would be used as well as direct data from Google Docs on how students used it. The goal of this study would be to inform instructors about the importance of how and when students need to integrate Google Docs to support their workflow.

-Investigation of the level of team awareness in relation to team success, and how a tool like Google Docs can affect team awareness. Surveys and interviews would measure individual team members' awareness level about their teammates' thinking processes, the problems team members were trying to solve, and thinking about their own thinking and work progress.

In the context of an engineering classroom where teamwork is central to the student educational experience, introduction of a new technology to help manage a complex process of teams' workflow management should be a deliberate instructional effort informed by educational research with the goal of helping students to become more aware of ways to use the tool to better coordinate their collaborative efforts and to more effectively support their communication.

The overall goal of this research is to contribute to the theoretical understanding of processes underlying the successful use of online technology to support teams' workflow and to inform instructional practice on how to integrate these findings in an engineering classroom setting.

REFERENCES

REFERENCES

ABET. (2014). *Criteria for accrediting engineering programs*. Baltimore: ABET, Inc. Retrieved from http://www.abet.org/wp-content/uploads/2015/05/E001-15-16-EAC-Criteria-03-10-15.pdf

Akyol, Z., & Garrison, D. R. (2011a). Assessin metacognition in an online community of inquiry. *Internet and Higher Education, 14*, 183-190.

Akyol, Z., & Garrison, D. R. (2011b). Understanding cognitive presence in an online and blended community of inquiry: Assessing outcomes and processes for deep approaches to learning. *British Journal of Educational Technology, 42*(2), 233-250.

Allen, I. E., & Seaman, J. (2010). Class Differences: Online Education in the United States, 2010. The Sloan Consortium.

Allen, I. E., & Seaman, J. (2011). Going the Distance: Online Education in the United States, 2011. The Sloan Consortium.

Baird, D. E., & Fisher, M. (2005). Neomillenial user experience design strategies: utilizing social networking media to support "always on" learning styles. *Journal of Educational Technology Systems*, *34*(1), 5-32.

Balamuralithara, B., & Woods, P. C. (2009). Virtual Laboratories in Engineering Education: The Simulation Lab and Remote Lab. *Computer Application Engineering Education, 17*, 108-118.

Borrego, M., Karlin, J., McNair, L., & Beddoes, K. (2013). Team Effectiveness Theory from Industrial and Organizational Psychology Applied to Engineering Student Project Teams: A Research Review. *Journal of Engineering Education, 102*(4), 472-512. doi: 10.1002/jee.20023

Bourne, J., Harris, D., & Mayadas, F. (2005). Online Engineering Education: Learning Anywhere, Anytime. *Journal of Engineering Education, 94*(1), 131-146.

Çakir, M. P., Zemel, A., & Stahl, G. (2009). The joint organization of interaction within a multimodal CSCL medium. *International Journal of Computer-Supported Collaborative Learning, 4*(2), 115-149.

Chao, J. (2007). Student Project Collaboration using Wikis. Retrieved from www.computer.org

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., Schauble, L. (2003). Design experiments in educational research. *Educational Researcher 32,* 1 (January-February), 9-12.

Cole, M. (2009). Using Wiki technology to support student engagement: Lessons from the trenches. *Computers and Education*, *52*, 141-146.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences, 13*(1), 15-42.

Cress, U., & Kimmerle, J. (2008). A systematic and cognitive view on collaborative knowledge building with wikis. *Computer Supported Collaborative Learning*, *3*, 105-122.

Dede, C. (2005). Why design-based research is both important and difficult. *Educational Technology, 45*, 1 (January-February), 5-8

Dillenbourg, P. (1999a). What do you mean by "collaborative learning"? In P. Dillenbourg, (Ed.), *Collaborative learning: Cognitive and computational approaches* (pp. 1-16). Amsterdam, NL: Pergamon, Elsevier Science.

Downey, G., Lucena, J. et al. (2006, April). The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently. *Journal of Engineering Education*, *95*(2), 107-122.

Edmondson, A. C. (2012). Teamwork on the fly. *Harvard Business Review*, *90*(4), 72-80.

Garrison, D. R. (2003). Cognitive presence for effective asynchronous online learning: The role of reflective inquiry, self-direction and metacognition. *Elements of quality online education: Practice and direction*, *4*, 47-58.

Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical Inquiry in a Text-Based Environment: Computer Conferencing in Higher Education. *The Internet and Higher Education, 2*, 87-105.

Greenhow, C., Robelia, B., & Hughes, J. E. (2009). Learning, Teaching, and Scholarship in a Digital Age. *Education Researcher*, *38*, 246.

Haag, S., & Palais, J. C. (2002). Engineering Online: Assessing Innovative Education. *Journal of Engineering Education, 91*(2), 285-290.

Hurtado, S., Eagan, K., Pryor, J. H., Whang, H., & Tran, S. (2012). Undergraduate teaching faculty: The 2010-2011 HERI faculty survey. *Higher Education Research Institute: University of California, Los Angeles.* Retrieved from http://www.heri.ucla.edu/monographs/HERI-FAC2011-Monograph.pdf

Johnson, D., Johnson, R., & Smith, K. (2007). The State of Cooperative Learning in Postsecondary and Professional Settings. *Educational Psychology Review, 19*(1), 15-29.

Johri, A. (2009). Preparing engineers for a global world: identifying and teaching strategies for sensemaking and creating new practices. In *Frontiers in Education Conference, 2009. FIE'09. 39th IEEE* (pp. 1-6). IEEE.

Johri, A. (2010). Global and virtual teamwork. *Journal of Engineering Education*, *99*(1), 93-96.

Johri, A. (2012). From a distance: Impression formation and impression accuracy among geographically distributed coworkers. *Computers in Human Behavior, 28*(6), 1997-2006.

Johri, A. (2014). Millennial engineers: Digital media and information ecology of engineering students. *Computers in Human Behavior*, *33,* 286-301

Kanuka, H., & Garrison, D. R. (2004). Cognitive Presence in Online Learning. *Journal of Computing in Higher Education, 15*(2), 21-39.

Katzenbach, J. R., & Smith, D. K. (1993). *The discipline of teams*. Harvard Business Press.

Kimmerle, J., Moskaliuk, J., & Cress, U. (2009). Understanding Learning - the Wiki Way. *WikiSym'09 Orlando, Florida, USA*. Retrieved from http://www.wikisym.org/ws2009/procfiles/p103-kimmerle.

Levin, A., S., Lenhart, A., & Rainie, L. (2002). *The digital disconnect: The widening gap between Internet-savvy students and their schools* (Washington, DC: Pew Internet and American Life Project). Retrieved from http://www.pewinternet.org/PPF/r/67/report_display.asp

Li Xu. (2007). Project the wiki way: using wiki for computer science course project management. *Journal of Computing Sciences in Colleges, 22*(6), 109-116

Loughry, M. L., Ohland, M. L., & Woehr, D. J. (2014). Assessing teamwork skills for assurance of learning using CATME Team Tools. *Journal of Marketing Education*, 36(1), 5-19.

Lucena, J., Downey, G., Jesiek, B., & Elber, S. (2008, October). Competencies Beyond Countries: The Re-Organization of Engineering Education in the United States, Europe, and Latin America. *Journal of Engineering Education*, *97*(4), 433-447.

Mayadas, F., Bourne, J., & Bacsich, P. (2009). Online Education Today. *Science, 323*(5910), 85-89.

Meisenzahl, R., Mokyr, J. (2010 [online it says 4/2011]). "The Rate and Direction of Invention in the British Industrial Revolution: Incentives and Institutions". Prepared for the conference on The Rate and Direction of Inventive Activity. Retrieved from http://www.nber.org/papers/w16993.ack

McAlister, S., Ravenscroft, A., & Scanlon, E. (2004). Combining interaction and context design to support collaborative argumentation using a tool for synchronous CMC. *Journal of Computer Assisted Learning: Special Issue: Developing Dialogue for Learning, 20*(3), 194–204

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). Qualitative data analysis: A methods sourcebook (3rd ed.). Thousand Oaks, CA: Sage.

National Academy of Engineering. (2005). *Educating the Engineer of 2020: Adapting Engineering Education to the New Century.* National Academies Press.

Neumann, D. L., & Hood, M. (2009). The effects of using a wiki on student engagement and learning of report writing skills in a university statistics course. *Australasian Journal of Educational Technology*, *25*(3), 382-398.

Ohland, M.W., Loughry, M.L., Woehr, D.J., Finelli, C.J., Bullard, L.G., Felder, R.M., Layton, R.A., Pomeranz, H.R., & Schmucker, D.G. (2012). The Comprehensive Assessment of Team Member Effectiveness: Development of a Behaviorally Anchored Rating Scale for Self and Peer Evaluation. *Academy of Management Learning & Education*, 11(4), 609-630.

Ohland, M.W., Giurintano, D., Novoselich, B., Brackin, P., Sangelkar, S. (2015). Supporting Successful Teams: Research to Practice in Capstone Courses. *International Journal of Engineering Education, 31*(6B), 1748–1759.

Parker, K. R., & Chao, J. (2007). Wiki as a teaching tool. *Interdisciplinary Journal of Knowledge and Learning Objects*, *3*, 57-72.

Pentland, A. (2012, April). The New Science of Building Great Teams. *Harvard Business Review*. Retrieved from https://hbr.org/2012/04/the-new-science-of-building-great-teams

Roschelle, J., & Teasley, S. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer-supported collaborative learning* (pp. 69-197).

Saldana, J. (2009). *The Coding Manual for Qualitative Researcher.* [Kindle 1.10]. Retrieved from Amazon.com

Scardamalia, M., & Bereiter, C. (2010). A Brief History of Knowledge Building. *Canadian Journal of Learning and Technology, 36*(1), 1-16.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 97-118). New York: Cambridge University Press.

Scardamalia, M., & Bereiter, C. (1996). Computer support for knowledge-building communities. In T. Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm* (pp. 249-268). Hillsdale, NJ: Lawrence Erlbaum Associates.

Smith, K. (1996). Cooperative Learning: Making "Groupwork" Work. *New Directions for Teaching and Learning 67*, 71-82.

Smith, K., Sheppard, S., Johnson, D., & Johnson, R. (2005). Pedagogies of Engagement: Classroom-Based Practices. *Journal of Engineering Education, 94*(1), 87-101.

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 409-426). Cambridge, UK: Cambridge University Press.

Stahl, G. (2004). Building collaborative knowing: Elements of a social theory of CSCL. In J.-W. Strijbos, P. Kirschner & R. Martens (Eds.), What we know about CSCL: And implementing it in higher education (pp. 53-86). Boston, MA: Kluwer Academic Publishers.

Svinicki, M. (2004). *Learning and Motivation in the Postsecondary Classroom.* San Francisco, CA: Jossey-Bass.

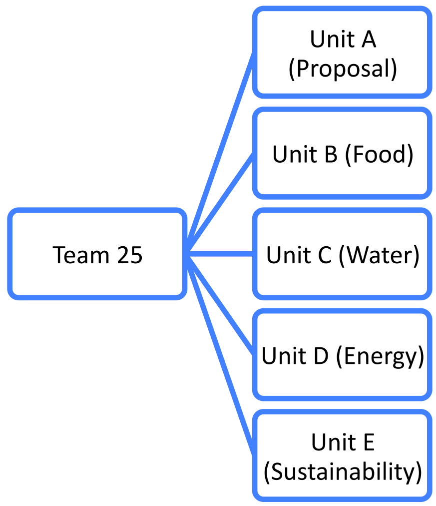
Transforming Undergraduate Education in Engineering Report (TUEE). (2014). Retrieved from https://www.asee.org/TUEE_PhaseI_WorkshopReport.pdf

Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education,* 46, 71-95.

APPENDICES

Appendix A Handout: Efficient Use of Google Docs (Original)

Organization Structure
To collaborate more efficiently with your teammates, it is important to create a folder organization structure that will help you to locate necessary files quickly and to contribute materials easily. Some of the most efficient teams from previous semesters used a simple structure consisting of Team #'s folder that contained folders for each of the Projects.
For example,



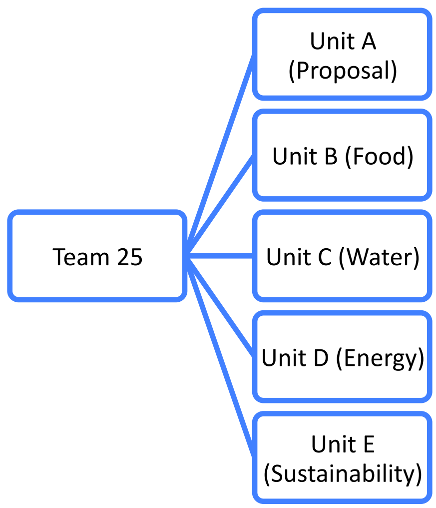
Note the importance of clearly labeling your folders *and* each document within these folders.
Remember, creating a simple folder organization structure and clearly labeling your folders and documents will save you time and minimize confusion among team members.

Use of the Google Docs Comments Feature
Each of the Google documents contains a COMMENTS feature located in the upper right corner of the screen. When you make changes to the document such as edits, new text addition, corrections, etc., it is important to write a comment or comments describing what you have done. Writing comments will help your team members understand what you did as well as to remind you of your thinking process throughout the project.

It is important to post at least one comment when you make any changes to the shared Google document. **This comment should contain a description of *what* you did as well as an explanation of *why* you made the addition or change**. Think of this comment as your debrief to your team members about your work progress and the rationale for your decision.

Appendix B Handout: Efficient Use of Google Docs (Modified)

Organization Structure
To collaborate more efficiently with your teammates, it is important to create a folder organization structure that will help you to locate necessary files quickly and to contribute materials easily. Some of the most efficient teams from previous semesters used a simple structure consisting of Team #'s folder that contained folders for each of the Projects.
For example,



Note the importance of clearly labeling your folders *and* each document within these folders.
Remember, creating a simple folder organization structure and clearly labeling your folders and documents will save you time and minimize confusion among team members.

Use of the Google Docs Comments Feature
Each of the Google documents contains a COMMENTS feature located in the upper right corner of the screen. When you make changes to the document such as edits, new text addition, corrections, etc., it is important to write a comment or comments describing what you have done. Writing comments will help your team members understand what you did as well as serve you as a reminder of your thinking process throughout the project.
It is important to post at least one comment when you make any changes to the shared Google document. **This comment should contain a description of *what* you did as well as an explanation of *why* you made the addition or change**. Think of this comment as your debrief to your team members about your work progress and the rationale for your decisions.

Why use COMMENTS?

To stay more connected to the project

- 84% either Agreed or Strongly Agreed that the use of the Comments feature helped them to stay more connected to the project in process

To help support your thinking process while working on the project

- 73% Agreed and Strongly Agreed that the use of the Google Docs Comments feature helped them to be more aware of their thinking process

To help teams move forward with the work more efficiently

- 75% Agreed and Strongly Agreed that the use of the Google Docs Comments feature helped their teams to move forward with the work more efficiently

Here is what students have to say about the *use of the Google Docs COMMENTS feature:*

"Helped avoid confusion and made our collaborative work more efficient"

"The ease of ability to ask questions helped group members who wouldn't ask questions in person have a voice"

"Enabled us to quickly clarify any discrepancies with regards to formatting, misleading or ambiguous phrasing, etc. Thus, we were all on the same page as to what our project was trying to communicate and how we wanted to do it, which definitely helped our efficiency and productivity"

"We could build on others' ideas, which inspired critical thinking"

"Allowed us to be on the same page as far as who's contributing/thinking about what"

"Helped us to have a dialogue without needing to be on the document at the same time"

"Added the ability to ask for or provide clarification without actually modifying the document"

"Helped us keep track for the project at hand"

"Allowed others to critique my writing where I had not been clear. I had to go back and think about how to fully explain my thoughts"

"Helped me explain my reasoning in what I contributed to the project when my other teammates wanted clarification"

Appendix C Institutional Review Board (IRB) Letter

PURDUE UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	RUTH STREVELER ARMS
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	03/07/2013
Committee Action:	**Exemption Granted**
IRB Action Date:	03/06/2013
IRB Protocol #:	1303013349
Study Title:	Evaluation of Educational Practices to Support Online Collaborative Learning in Engineering

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b)(1) .

If you wish to make changes to this study, please refer to our guidance "**Minor Changes Not Requiring Review**" located on our website at http://www.irb.purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms page of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without

proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 1

- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Categories 2 and 3

- Surveys and questionnaires should indicate
  - only participants 18 years of age and over are eligible to participate in the research; and
  - that participation is voluntary; and
  - that any questions may be skipped; and
  - include the investigator's name and contact information.
- Investigators should explain to participants the amount of time required to participate. Additionally, they should explain to participants how confidentiality will be maintained or if it will not be maintained.
- When conducting focus group research, investigators cannot guarantee that all participants in the focus group will maintain the confidentiality of other group participants. The investigator should make participants aware of this potential for breach of confidentiality.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 6

- Surveys and data collection instruments should note that participation is voluntary.
- Surveys and data collection instruments should note that participants may skip any questions.
- When taste testing foods which are highly allergenic (e.g., peanuts, milk, etc.) investigators should disclose the possibility of a reaction to potential subjects.

Ernest C. Young Hall, 10th Floor - 155 S. Grant St. - West Lafayette, IN 47907-2114 - (765) 494-5942 - Fax: (765) 494-9911

Appendix D Baseline Survey (Phase 1)

Q1: Please write your Student ID in the space provided

Q2: How old are you?

Q3: In your opinion, what are some of the important abilities that an engineer should develop?

Q4: In your own words please describe an engineering design reasoning process.

Q5: How frequently do you think you use the engineering design process when solving engineering problems?
Never Rarely Sometimes Often Always

Q6: Please respond to the following statements:
I like to collaborate on projects with my classmates.
Strongly Agree Disagree Neutral Agree Strongly Agree
I am usually an active participant in my team.
Strongly Agree Disagree Neutral Agree Strongly Agree
I develop new skills and knowledge from other members in my team.
Strongly Agree Disagree Neutral Agree Strongly Agree

Q7: I have worked collaboratively in online environments.
Yes No

Q8: Working collaboratively in an online environment is better than working in a face-to-face environment.
Strongly Agree Disagree Neutral Agree Strongly Agree

Q9: Please indicate to what extent you use the following Internet technologies for personal communication, university classes or workspace, if applicable:

Twitter Never Used Rarely Occasionally Frequently
- Personal
- Classes
- Work

Facebook
LinkedIn
Personal Blog
Texting
Skype
Google Groups or other email lists
Google Docs
Blackboard
Texting
Social Bookmarking (Digg or Delicious)
Podcasts
Wikis of any kind
RSS feeds
SourceForge

Q10: Other, please explain.

Appendix E Baseline Survey (Phase 2)

Q1: Please write your Student ID in the space provided.

Q2: How old are you?

Q3: Do you have experience working in the field of engineering?

None Summer Internship Less than 2 years 3-5 years More than 5 years

Q4: In your opinion, what are some of the important abilities that an engineer should develop?

Q5: How much do you think collaborative work is important to an engineering profession?

Not important Somewhat important Important Very Important

Q6: Please explain what "working collaboratively" means to you.

Q7: Please respond to the following statements:

I like to collaborate on projects with my classmates.
Strongly Agree Disagree Neutral Agree Strongly Agree

I am usually an active participant in my team.
Strongly Agree Disagree Neutral Agree Strongly Agree

I develop new skills and knowledge from other members in my team.
Strongly Agree Disagree Neutral Agree Strongly Agree

Q8: I have worked collaboratively in online environments in prior engineering classes.
Yes No

Q9: If you answered yes, please respond to the following statements:

I found collaborative online environments useful in making work process more efficient.
Strongly Agree Disagree Neutral Agree Strongly Agree

I found collaborative online environments useful in supporting the thinking process of the group.
Strongly Agree Disagree Neutral Agree Strongly Agree

I found collaborative online environments useful in helping me be more reflective about my work.
Strongly Agree Disagree Neutral Agree Strongly Agree

Q10: Do you think working collaboratively in an online environment is better than working in a face-to-face environment? Please explain.

Q11: Please indicate to what extent you use the following Internet technologies for personal communication, university classes or workspace, if applicable

Twitter	Never Used	Rarely	Occasionally	Frequently
• Personal				
• Classes				
• Work				
Facebook				
LinkedIn				
Google Groups or other email lists				
Google Docs				
Personal Blog				
GroupMe Texting				
Skype				
Social Bookmarking (Digg or Delicious)				
Podcasts				
Wikis of any kind				
RSS feeds				

Q12: Other, please explain

Appendix F Reflection Survey (Phase 1)

Q1: Please write your Student ID in the space provided.

Q2: While working on the Energy Unit with your team, how many times did you meet face-to-face to discuss your work?
None 1-2 times 3-4 times 5-6 times More than 7 times

Q3: What collaborative software did your team use to support your work process?
Google Docs Wiki Other

Q4: If you selected Other, please specify the software.

Q5: If your team used Google Docs,Wiki or Other software tools, please select the tasks you used it for:

Keeping in touch with team members	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Recording meeting notes	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Outlining work tasks/schedule	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Brainstorming ideas	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Keeping a record of literature findings	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Co-writing the final document	Never	1-2 times	3-4 times	5-6 times	More than 7 times

Q6: Did you use software tools for other tasks? If yes, please explain:

Q7: Please explain in what ways the collaborative software your team used was or wasn't helpful in supporting your team's design process.

Q8: What other technologies did you use to communicate and work together with your teammates?

Phones (voice)	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Phones (text)	Never	1-2 times	3-4 times	5-6 times	More than 7 times
E-mail	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Facebook	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Twitter	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Instant Messaging	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Video conferencing	Never	1-2 times	3-4 times	5-6 times	More than 7 times

Q9: If you used other technologies, please explain.

Q10: Please rate how well you think your team managed

Time	Very good	Good	Fair	Poor
Setting goals and Work planning	Very good	Good	Fair	Poor
Decision making	Very good	Good	Fair	Poor
Communication (face-to-face)	Very good	Good	Fair	Poor
Communication (with technology support)	Very good	Good	Fair	Poor
Ideas and Opinions sharing	Very good	Good	Fair	Poor
Problem solving	Very good	Good	Fair	Poor
Conflict	Very good	Good	Fair	Poor

Q11: What were some of the things your team did to increase the potential for success?

Q12: What were some of the weaknesses of your team?

Appendix G Reflection Survey (Phase 2)

Q1: Please write your Student ID in the space provided.

Q2: While working on the Energy Unit with your team, how many times did you meet face-to-face to discuss your work?
None 1-2 times 3-4 times 5-6 times More than 7 times

Q3: What collaborative software did your team use to support your work process?
Google Docs Wiki Other

Q4: If you selected Other, please specify the software.

Q5: If your team used Google Docs, Wiki or Other software tools, please select the tasks you used it for.

Keeping in touch with team members	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Recording meeting notes	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Outlining work tasks/schedule	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Brainstorming ideas	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Keeping a record of literature findings	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Co-writing the final document	Never	1-2 times	3-4 times	5-6 times	More than 7 times

Q6: If you used software tools for other tasks, please explain.

Q7: Please explain in what ways the collaborative software your team used was or wasn't helpful in supporting your team's design process.

Q8: If your team used Google Docs, did your team members use the Comments feature?
Yes No Not sure what that is

Q9: If your team used the Comments feature, what the comments were used for?

Explained individual contributions to the document so that other team members could understand what changes you made.
Asked your team members to make edits to citations, formatting, units, text.
Asked your team members to clarify content by explaining the meaning of a written text, formula, etc.
Other ___________________

Q10: If you selected Other in previous question, please explain.

Q11: While working on the Energy Unit, how frequently did you

Check for new comments posted by your teammates	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Post your own comments	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Respond to any of the posted comments	Never	1-2 times	3-4 times	5-6 times	More than 7 times

Q12: Would you agree that the use of the Comments feature helped you to stay more connected to the project work?
Strongly Agree Disagree Neutral Agree Strongly Agree

Q13: Please explain your answer to previous question.

Q14: Would you agree that the use of the Google Docs Comments feature while working on the Energy Unit helped you to be more aware of:

The thinking process of your team members	Strongly Agree	Disagree	Neutral	Agree	Strongly Agree
The problems that you team members are trying to resolve	Strongly Agree	Disagree	Neutral	Agree	Strongly Agree
The overall team's work progress	Strongly Agree	Disagree	Neutral	Agree	Strongly Agree
Your own thinking process	Strongly Agree	Disagree	Neutral	Agree	Strongly Agree
Your own work progress	Strongly Agree	Disagree	Neutral	Agree	Strongly Agree

Q15: In your opinion, was the use of the Comments feature useful in supporting your own thinking process and your team's thinking process while working on the Energy Unit? Please explain.

Q16: Would you agree that the use of the Google Docs Comments feature helped your team to move forward with the work more efficiently?

Strongly Agree Disagree Neutral Agree Strongly Agree

Q17: Please explain your answer to the previous question.

Q18: What other technologies did you use to communicate and work together with your teammates?

Phones (voice)	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Phones (text)	Never	1-2 times	3-4 times	5-6 times	More than 7 times
E-mail	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Facebook	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Twitter	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Instant Messaging	Never	1-2 times	3-4 times	5-6 times	More than 7 times
Video conferencing	Never	1-2 times	3-4 times	5-6 times	More than 7 times

Q19: If you used other technologies, please explain.

Q20: Please rate how well you think your team managed:

Time	Very good	Good	Fair	Poor
Setting goals and Work planning	Very good	Good	Fair	Poor
Decision making	Very good	Good	Fair	Poor
Communication (face-to-face)	Very good	Good	Fair	Poor
Communication (with technology support)	Very good	Good	Fair	Poor
Ideas and Opinions sharing	Very good	Good	Fair	Poor
Problem solving	Very good	Good	Fair	Poor
Conflict	Very good	Good	Fair	Poor

Q21: What were some of the things your team did to increase the potential for success?

Q22: What were some of the weaknesses of your team?

Appendix H Institutional Review Board (IRB) Approval Letter for Interview

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	STREVELER, RUTH A
From:	DICLEMENTI, JEANNIE D, Chair Social Science IRB
Date:	08 / 04 / 2015
Committee Action:	Amended Exemption Granted
Action Date:	08 / 03 / 2015
Protocol Number:	1303013349
Study Title:	Evaluation of Educational Practices to Support Online Collaborative Learning in Engineering

The Institutional Review Board (IRB) has reviewed the above-referenced amended project and has determined that it remains exempt.

If you wish to make changes to this study, please refer to our guidance"**Minor Changes Not Requiring Review**" located on our website at http://www.irb/purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms pages of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit

the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 1

- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Categories 2 and 3

- Surveys and questionnaires should indicate
  - only participants 18 years of age and over are eligible to participate in the research; and
  - that participation is voluntary; and
  - that any questions may be skipped; and
  - include the investigator's name and contact information.
- Investigators should explain to participants the amount of time required to participate. Additionally, they should explain to participants how confidentiality will be maintained or if it will not be maintained.
- When conducting focus group research, investigators cannot guarantee that all participants in the focus group will maintain the confidentiality of other group participants. The investigator should make participants aware of this potential for breach of confidentiality.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 6

- Surveys and data collection instruments should note that participation is voluntary.
- Surveys and data collection instruments should note that participants may skip any questions.
- When taste testing foods which are highly allergenic (e.g., peanuts, milk, etc.) investigators should disclose the possibility of a reaction to potential subjects.

VITA

VITA

Nataliia P. Perova-Mello received a Bachelor of Science degree in Electrical Engineering from Suffolk University in 2002, a Master of Science degree in Electrical Engineering from Tufts University in 2005 and a Master of Science degree in Mathematics, Science, Technology and Engineering education from Tufts University in 2008. While in graduate school, she worked as a physics and environmental engineering instructor at Suffolk University and a research assistant at the Center for Engineering Education Outreach at Tufts University. In 2008, Nataliia started working on an algebra learning project as a research assistant in the Graduate School of Education at Harvard University.

Nataliia joined the School of Engineering Education at Purdue University to pursue her long-term research interest in engineering instruction. Her research is focused on investigating how teams of engineering students use online tools to support their workflow management process and what implications it has on engineering instruction. She is planning to continue her research into online learning tools while seeking to apply her findings in instruction and relevant Post Doc positions.