Engineering Design Instruction Using Slack for Project Support and Teamwork

Dr. Jonathan Elliot Gaines, University of South Florida

Jonathan E. Gaines is faculty in the Mechanical Engineering Department at the University of South Florida. He is the Director of First Year Experiential Education and Learning. Through this position, he develops and implements the curriculum for USF's Foundations of Engineering Lab course. He is also the Principle Investigator for Bulls Engineering Youth Experience (Bulls-EYE Mentoring) a Science, Technology, Engineering, and Math based outreach program that uses undergraduate students to mentor middle school youth.

Dr. Olukemi Akintewe, University of South Florida

Dr. Olukemi Akintewe is an instructor in the Department of Medical Engineering. She received a B.E. degree in chemical engineering from City College of New York, CUNY, a M.Sc in materials science & engineering from The Ohio State University and a Ph.D. in chemical engineering from the University of South Florida. Dr. Akintewe has focused her research in service-learning in engineering education; engineering predictive assessment models that supports students' learning, classroom management techniques and best teaching practices.

Dr. Schinnel Kylan Small, University of South Florida

Schinnel Small is an Instructor I and IT Director at the University of South Florida. She pursued a Bachelor-to-Doctorate path of study at Morgan State University and obtained her Bachelor of Science and Doctorate degrees in Electrical and Computer Engineering in 2004 and 2010 respectively. She currently teaches Introductory Programming and Engineering courses for the Department of Computer Science and Engineering. As an IT coordinator, she assists the department with IT curriculum and course development, as well as advising for IT students. Her research interests include programming languages and visual analytics.

Terreonn Henry

Engineering design instruction using Slack for project support and teamwork

Abstract

This Design Methodologies paper presents the design process and technology used to facilitate a first-year, service-learning based engineering design course at the University of South Florida. The course is facilitated using a cloud-based collaboration tool called Slack which allows individuals to be organized and assigned to channels for easy dissemination of information. The nature of the Slack channels offered evolves throughout the semester to mirror the needs of the design process. This paper presents the strategy used to leverage Slack and administer the design process. The general structure of the course is presented before and after the use of Slack. The future direction of the course is also given along with discussion of potential improvements.

Introduction to social software

Design thinking is hard to learn and just as hard to teach [1]. This is partially because communication, which is a central focus for engineering design can be challenging. Design projects often require multiple modes of communication with a variety of stakeholders including employers, community partners, peers, and customers. As such, when teaching engineering design, instructors often seek to improve the quality of communication, making it more useful, natural, or enjoyable. Electronic learning tools (E-learning tools) are sometimes used to enhance the design experience for this purpose [2]–[5]. Because technology is so pervasive in our society today, better engineering design instruction might be achieved through understanding the strengths and limitations of these tools. In the engineering context, their effectiveness is oftentimes judged based on how students use them to 1. Adjust to different settings, 2. Integrate their already developed skills as "digital natives", 3. Simulate real-world engineering environments, or 4. Provide alternatives to traditional one-way instruction that are more suitable for design [6]. Contemporary tools offer users opportunity to be content creators when using electronic media, allowing for even more creativity and autonomy in design instruction [7], [8].

This paper focuses on the use of Slack, a cloud-based social software and its applications in first year engineering design. How Slack facilitates learning, course inquiry and group interactions among engineering students, faculty members and student assistants is discussed. In addition, the impact and correlation to good pedagogical principles are also explored. Social software is any e-learning tool that is designed for collaborative purposes and introduced to help with user self-determination of content generation. They traditionally come in the form of wikis, blogs, or forums [6], [9]–[11]. Bernsteiner [6] describes social software as follows

> "Social software emerged and came into use in 2002 and is generally attributed to Clay Shirky (2003). Shirky … defines social software simply as "software that supports group interaction." Another definition of social software can be found in Coates (2005), who refers to social software as "software that supports, extends, or derives added value from human social behaviour." Users are no longer mere readers, audiences, or consumers. They have the ability to become active producers of content. Users can act in user and producer positions and they can rapidly change the position." – pg 18

Therefore, not only does the software introduce new modes of communication that might be relevant for collaboration but new models of teaching and learning are also introduced. In grasping potential models for teaching and learning, Baumgartner [12] describes a hierarchal model that is applicable for the introduction of social software to teach engineering.

- **Learning and teaching I, transferring knowledge:** At the starting point, the learner needs to be provided with abstract knowledge to lay the theoretical foundations and to understand relevant signposts, road markings, and orientation points. This kind of factual knowledge is static and has little value by itself in real and complex situations. It merely serves as a shortcut to prevent pitfalls and to help to organize the student's learning experiences. The knowledge of the student is based on knowledge possessed by the teacher. Students have to learn what teachers ask them to learn. The teacher has the responsibility to make the knowledge transfer as easy as possible.
- **Learning and teaching II, acquiring, compiling, and gathering knowledge:** In this section of the individual learning career, the student actually applies the abstract knowledge and gathers his or her own experiences. In order to limit the action and reflection possibilities, the learner interacts within a somewhat restricted, artificial environment, which is reduced in complexity and easy to control by the teacher. To provide feedback, the learning environment is designed to include relevant devices where students can deposit their interim products and teachers can inspect them. The emphasis in this model lies on the learning process of the student. Teachers try to help the students overcome wrong assumptions and wrong learning attitudes, and assist in the reflection process of the subject domain.
- **Learning and teaching III, developing, inventing, and constructing knowledge:** Teacher and learner work together to master problems. This model includes problem generation and/or invention. The environment is constructed in such a way that it represents, at least in certain aspects, reality or reality in a constrained form. This model includes two-way communication on equal terms, using either linguistic representations or other adequate kinds of language. Teaching III has strong links to constructivism. From a constructivist point of view, learning is considered as an active process in which people construct their knowledge by relating it to their previous experiences in complex and real situations in life. In their practical lives, people are confronted with unique, unpredictable situations whose inherent problems are not readily observable. Students should be enabled to invent new things, and produce or generate new knowledge.

Baumgartner goes on to say "Learning and teaching at universities in most cases can be assigned to the requirements presented in Learning and Teaching II and III. In order to achieve this goal, a special learning environment must be provided". This need is particularly true for project-based, engineering design courses which rely on varying degrees of analysis, synthesis, and originality.

Some social softwares have been used for Learning and Teaching III. Richards [13] introduced a framework for effective social software. According to Richards, social software should
1. Build a shared repository which achieves a common understanding and structure together with a means of finding out what projects or problems people are working on (providing opportunities for sharing and reuse);
2. Allow people to create content in their own way using their own terms and concepts;

3. Develop a top-down knowledge map in the form of an ontology or concept map to assist people to define and structure their own concepts within the bigger picture
4. Allow the knowledge nuggets to emerge bottom-up, or top-down where appropriate, in an ad hoc, immediate and spontaneous manner.
5. Support a range of expertise levels, views of the knowledge and access rights;
6. Provide a review process in which users can register their approval or disagreement;
7. Test and keep track of the consistency between all elements of the knowledge system and notify users when conflicts occur;
8. Be compatible with a wide range of existing systems and knowledge sources;
9. Provide an intuitive, simple and yet structured knowledge maintenance cycle;
10. Support primary ownership and management of the domain knowledge by domain users, not a third party such as a knowledge engineer.
11. Be configurable to each enterprise allowing changes to the ontology, the workflow/process of acquiring knowledge and the user interface over the life of the system.

No one social software is optimized in all 11 areas or is best for every context. This framework will be used in this paper to judge the quality and present the strategy for use of a particular social software called Slack towards design thinking and Learning and Teaching model III. Within the context of first year engineering design for large lecture courses, the strengths and weaknesses of Slack will be discussed along with how the approach evolved over time.

Introduction to Slack

Slack is a cloud based group collaboration social software that provides for synchronous and asynchronous communication [14], [15]. Of the similar options on the market, it is the one with the largest user base, having over 10 million daily active users in 2019 [16], up from 5 million daily users in 2016 [17] and 3 million daily users in 2012 [18]. Its functionality is best understood as an aggregation of other softwares. For example, Slack relies on users subscribing to channels, much like YouTube, to receive content with each channel having a purpose. A channel once joined resembles a chat interface, allowing for synchronous communication as users freely post their content of choice. The posting of content is similar to what one might find with a chat messaging interface like Facebook Messenger. A variety of different types of media can be posted including text, video, documents, etc. Central to its functionality is the process of 1. Organizing collaboration using channels, 2. Posting useful content within channels, and 3. Providing means to easily search that content in an effective manner [14], [15]. The popularity of the software has grown in recent years because if its streamlined user interface and integration with 3rd party add-ons called apps [15], [17], [19] which can be used to make the experience even more customizable [14]. Slack is marketed to companies who want to improve their productivity by enhancing individual, team, and company-wide interactions [17].

Recently, Slack has gained more traction in academia but has not been studied extensively [20]. Some practitioners have published their approach using Slack to enhance communication and collaboration in higher education. Because software developers use it a lot outside of academia, one application of Slack in the classroom is in software development [17], [21]. Additionally, the software has been used to support scientific research [19], [22], student seminar reflection and

collaboration, and graduate thesis work [14], [18]. These are examples of Slack's use as a collaborative tool for students. But, research on Slack's use in the classroom is very limited especially when considering its potential in an engineering design context.

EGN3000L is the course presented in this paper. The most similar implementation of Slack found to EGN3000L was for a post- graduate course in management and economics [23] because of the scale of the course, strategy for teaming, and focus on Learning and Teaching model III. The course organized 187 students between ten different project teams. Within each team, students were assigned one of four roles and asked to collaborate with others on their team to design or create a new product. Students in this course found Slack to be at its best when an environment of mutual trust, strong social influence, and reward valence was created [23]. No example using Slack in an interdisciplinary, engineering design context was found in the literature. The article by Zhang et al. [23] was the only example of Slack's use to support a relatively large course. Some defining characteristics of EGN3000L that differ from Zhang et al. [23] are 1. EGN3000L is only for first year students, 2. EGN3000L is interdisciplinary, 3. EGN3000L has a large enrollment of over 500 students, 4. EGN3000L is engineering design based, and 5. Students collaborate in teams of five while completing a 15 week project in EGN3000L. Common to Zhang et al. [23], students are required to use Slack, adopt roles on their teams, and are asked to collaborate to create a new product. In EGN3000L, students have a different emphasis on the engineering design process and skill development from the experience.

In the limited evidence found in the literature, factors of consideration for using Slack vary based on application with some common themes including the need to 1. Leverage Slack's social aspects to increase engagement for users [20], [23], 2. Integrate 3rd party apps to increase Slack's effectiveness [15], [19], Clarify expectations for how students should download and use Slack [14], [15], and 4. Communicate why using Slack is important and what students should expect to get out of it [23]. All of these considerations were a focus in this implementation of Slack.

One other primary consideration for understanding the approach used in this paper is clarity on the versions of Slack that are offered. Slack offers two major options for use—a free version and a paid version [22]. The paid version of Slack allows for access to the entire message history, unlimited apps and integrations, and 10GB of storage per person using the software. At the same time, the paid version also costs $6.67 per person using the software which makes it cost prohibitive for large lecture courses. The free version of Slack restricts the number of posts that are searchable to the most recent 10,000 messages, caps the cloud storage space available through Slack to 5GB between all users, and limits the number of apps that can be integrated to 10 at any one time. Because one objective of this paper is to discuss Slack's implementation in a large lecture course, only the free version of Slack is considered in this paper beyond this point.

Social Software examples

The more relevant examples in the literature of social software to support engineering design correspond to other types of social softwares used for academic purposes. Table 1 provides a

comparison of common social-softwares to Slack based on Richards [13] framework. A plus is given for a strength and a minus for a perceived weakness. As shown, Slack is relatively strong in comparison to others at item 8, which is compatibility and flexibility, and relatively weak at item 9 which is an intuitive knowledge management cycle. The weakness for item 9 is a function of limitations associated with Slack's free version that makes previously posted content inaccessible once you reach certain thresholds of activity. Item 8 is a strength because of Slack's ease of use and flexibility both with configuring its core settings and in integrating 3rd party apps.

Table 1: Strengths/weaknesses of social softwares with respect to the Richards [13] framework

	Social software framework items 1-11 from Richards [13]										
	1	2	3	4	5	6	7	8	9	10	11
Blog	−	+	+	+		−	−	−		+	
Wiki		+	+	+	−		−	−		+	−
Forum		+	−	+		+	−	−	+		−
Creative Commons	+	+		−	+	−		−	+	−	
Slack	−	+			+	+	−	+	−	−	

The strengths and weaknesses of other social softwares are provided. Many have had success using wikis with engineering design instruction if the approach addressed these considerations [24]–[26]. Wikis are webpages where the content is editable by the consumers of the content. Based on the Richards [13] framework, wikis are strongest at items 2, 3, 4, and 10 and weakest at items 5, 7, 8, and 11. One strong aspect of wikis is allowing for concept creation on the user's own terms. They also support primary management of the knowledge by users and not management. One clear challenge with wikis is in the review, maintenance, and consistency of knowledge in the event there is disagreement. The use of wikis has raised questions in the literature about the push and pull between too little and too much user control of content.

Creative commons are one example where users keep a repository of original designs that respect original authorship but provided for flexibility in remixing said content. The approach is most useful when the primary concerns are item 5 on access rights and item 9 on providing a simple and structured knowledge maintenance cycle. Conflict pertaining to access rights and a lack of buy-in when content is removed has proven to be critical in some contexts [27]. With creative commons, Strict version control ensures each contribution is documented and owned by the creator [28]. A focus on ownership and maintenance of knowledge has the effect of weaknesses in other areas like items 4 and 8 which rely on more freedom inherent in the social software.

Other branches of social software used in an engineering design context include forums and blogs [8], [29]–[31]. A wide variety of forums exists where users can post and organize content online. Blogs are a type of forum where information is presented in reverse chronological order. The success of these tools is often dependent on their structure and the way in which they are implemented. Their platforms are often intuitive and simple to use while providing for the effective organization of content. Considering the Richards [13] framework, forums typically tie

in a review process to posts whereas blogs do not, making forums strong on item 6 while blogs are typically weak. Both social softwares post content in a chronological order but blogs typically leverage side panels useful for structuring content within a bigger picture, providing a strength with item 3. Previous forum posts can be difficult to tie into the big picture.

As shown in the table, Slack is strongest at items 2, 5, 6, and 8 and weakest in items 1, 7, 9, and 10. Slack provides a lot of options for customizability of user types and preferences, making it particularly effective at item 5. Slack also provides the ability to use emojis to articulate approval or disapproval for any type of content that is posted. This is a secondary feature but allows for effective integration of item 6. And lastly, item 8 is a central focus of Slack which provides a lot of flexibility to integrate other sources of knowledge easily using channels. Many of the weaknesses of Slack can be addressed through 3rd party apps. However, with the free version there are some very pronounced weaknesses that are tied to limitations on the number of messages that are searchable and the amount of cloud storage that is available in the free version.

The one strength each social software has in common is item 2 which pertains to the ability to create original content on the user's own terms and with autonomy. With Learning and Teaching III being important for engineering design instruction, item 2 is why social software use to support engineering design is of interest. The question then becomes "Which social software might be most useful and in what context?" For the social softwares mentioned, most strengths can be made stronger and weaknesses can be mitigated with deliberate decisions on how each social software is used. It is also possible that certain strengths can be lost based on decisions made by practitioners. This paper provides an example application for use of Slack to support an interdisciplinary, first-year, engineering design course. The paper also focuses on how Slack's flexibility through the integration of 3rd party apps and control over the structure of its channels can be leveraged to address key weaknesses of the social software to improve the course. The Richards [13] framework is then used as a baseline to discuss the impact of decisions made to most effectively use Slack. The structure of the course and how Slack was used during the Fall 2018 semester is presented along with the current structure of the course being used in the Spring 2019 semester. The authors use reflections by instructors of the course and a discussion of each implementation's strengths and weaknesses to frame how faculty have attempted to change the course for the better in light of the Richards [13] framework. The use of social software was thought to be a defining characteristic of the presented course which is used to introduce freshman students to Learning and Teaching model III. A discussion is then provided on how the curriculum might be improved in the future or leveraged by other faculty or practitioners.

Course Structure - Full Course

Beginning in the Fall 2018 semester, Slack was introduced to solve issues with a course called EGN3000L that had been piloted during the Fall 2017 and Spring 2018 semesters. While the pilot taught 84 students in the Fall 2017 semester, approximately 500 students took the full course in the Fall of 2018. Some defining characteristics of the Fall 2018 course structure were

1. **Credit:** The course was 3-credit hours and taught twice a week during a 75 minute class period for 15 weeks. The first lecture of the week covers the engineering concepts and design process while the second lecture focuses on students learning by doing.

2. **Interdisciplinary:** Students taking the course were from all of the departments in the College of Engineering. These departments included mechanical engineering, electrical engineering, civil/environmental engineering, industrial engineering, chemical/biomedical engineering, and computer science/IT/Cybersecurity/computer engineering.
3. **First-year:** All first-year students in the College of Engineering take the course as freshmen.
4. **Project-based service-learning:** The pilot course was service-learning based.
    a. One service-learning project was the focus of all 15 weeks of instruction with students both designing, fabricating, and testing real hardware to deliver to a community partner.
    b. Students designed hardware and STEM education based learning materials for faculty parents of middle school kids working at the university.
    c. The advising process was done during two design reviews where faculty met students.
    d. Students delivered final projects to faculty during a showcase at the end of the semester.
5. **Learning and teaching management:** The course is administered through a learning management software (Canvas) and Slack. All course materials and assignments were posted on the LMS while all project related information was managed on Slack.
6. **Project Assignment:** The seven projects offered were Speaker project, App Development, Microscope, Remote sensing, Robotics, Community Garden project and Fuel Cell project. Slack channels were created for each project. The detailed description of each project was pinned to the top of the respective channels. A total of at least 3 different types of projects were offered in each section. Students were provided with the list of projects, the detailed descriptions and were asked to rank their preference. Based on the student's first or second choice of selected project, they were paired in a group with a maximum number of 5 students.
7. **Individual and Group Assignments:** In the first five weeks of the course, students were assigned individual assignments primarily based on computer aided drafting (CAD) software where each student mock up their cosmetic and functional designs. In addition to that, individual assignments on ethics, intellectual property, and professional development were assigned. From the sixth week, students worked in their project groups and the group assignment varied from fabrication of their final CAD designs to design review presentations.
8. **Peer interactions and Project Roles:** Students mirrored real professional interactions.
    a. Students first worked as individuals and mocked up their ideas in CAD week 1-4.
    b. Students received group assignments at the start of week 5. Students then worked in groups of 4 or 5 to complete the ideation phase.
    c. Mid-semester, group members adapted roles on their teams: engineering technology lead, internal communications lead, educational materials lead, external communications lead and 3D printing/manufacturing lead.
9. **Fabrication:** Groups had to fabricate either a working prototype or a model of their final design. The model option was only available for selected project types where a physical manifestation of their final deliverable may have been difficult to achieve.
10. **Course Director:** The instructor for the pilot authored the new curriculum and became the course director for the Fall 2018 version. For consistency, the course director facilitated the project experience for all sections by doing the following
    a. The course director taught the first lecture of the week for all sections which was focused on the design process, project support, fabrication skills, and communication.
    b. The course director used Slack to address many of the challenges with communication of the pilot. The social software helped facilitate communication with students individually, within their groups, and as a 500-person cohort.

c. The course director coordinated the student assistants during weekly meetings.
d. The course director held a weekly meeting with course faculty.
e. The course director uploaded files and assignments on the learning management system.

10. **Course Faculty:** Eight faculty members facilitated the course. One of the faculty members was the course director whose responsibilities included ensuring that the seven faculty members consistently delivered the course outcomes. The seven faculty members were the assigned instructors for each course sections. Each section offered as least 3 projects selected by the course faculty. The teach-the-teacher model was adopted for the first lecture of the week in which the director lectured in the classroom while the course faculty observed. However, in the second lecture of the week, the course faculty facilitated class activities.

11. **Student Assistants**: Each course section had two student assistants whose responsibility includes monitoring Slack channels, student's attendance, assisting with project materials and grading. Some of the SAs had additional roles for the whole course such as directing the 3D printing training, managing the hardware materials for each project, supervising the meetings with the community partners and so forth.

Faculty members were required to attend the first lecture of the week and observe the course director facilitate project work. They then taught during the second lecture period of each week to make connections to the project experience and solidify concepts. In addition, the student assistants also were active voices on Slack, providing students with support. So, the course director leveraged Slack and played an active role in its implementation and use.

Table 2 provides the characteristics of the Fall 2018 implementation of Slack used for the EGN3000L course after deliberate decisions were made to improve the experience for an engineering design context. One primary change was the decision to provide more oversight to communication than what would traditionally be encountered in a social software. As a result, items 4 and 5 in the Richards [13] framework became weaknesses. Item 4 and 5 are related to allowing knowledge generation to be free flowing and organic. Students had the freedom to post information at will but because of the inclusion of the course director and student assistants, the environment focused more on the dissemination of important information as opposed to spontaneous creation of content or multiple perspectives on the knowledge.

Table 2: Strengths/weaknesses of Slack in comparison to the implementation done in the Fall of 2018 for EGN3000L. Comparison is with respect to the Richards [13] framework

	Social software framework items 1-11 from Richards [13]										
	1	2	3	4	5	6	7	8	9	10	11
Slack	–	+			+	+	–	+	–	–	
Slack - Fall 2018	–	+	+	–	–	+	–	+	–	–	+

The primary benefit to making this change was an improvement for item 3 and item 11 in the framework. Public channels were organized by the course director to provide communication for what the course director deemed to be important topics. Students still retained the ability to direct message each other and they could spontaneously create their own private channels which helped the course maintain a strength for item 2. During the course, the director changed which public

channels were offered, allowing for flexibility and configurability. The Fall 2018 implementation took advantage of Slack's flexibility to provide important channels for learning and to facilitate the project support for the class through the course director and specific channel offerings.

Because the course director and student assistants controlled the public channels, an additional benefit was the ability to create deviations from the core course content in a well-supported manner. To adapt to new students entering the class from other disciplines and departments, the project offerings shifted. For instance, the Computer Science students were offered App Development as a project. Students who pursued this project were able to develop an App using Google App Maker, which allowed them to design and implement the app without exposing them entirely to the back-end code responsible for their creations. This was necessary, since many of the students were not yet familiar with some of the technical knowledge that may be typically expected of a CS student performing this task. This new project was also unique in that it did not have the same amount of hardware requirements as other projects. This meant that the some of the hardware-oriented project tasks had to be modified to ensure that the students could experience the elements of engineering design without creating a physical prototype. Specific channels were added to the Slack interface in support of this effort.

Using slack to improve communication

To understand the opportunities for improvement as Slack was first introduced, the pilot course was looked at critically. During the pilot, students completed a semester long engineering design experience. One project choice was a community garden project where a group of 4-5 students completed a semester long design experience as part of the course. A student commented on the structure of the course while alluding to the value and uncomfortableness of open-ended design.

> "Vagueness [of our problem statement] gave us a lot of room to work with, and through group meetings and the sharing of ideas we came up with the required three to four ideas. Those ideas were designed and refined, but eventually as a group we had to come down to one idea as the class progressed. The Idea we came down to was my idea of a Vertical Garden that would use the same footprint as the planters in the community garden however optimizing crop production by the use of increased verticality. The preliminary design in shown in Figure 1a. This design was refined due to given criteria such as ease of use, weight and size restriction, ease of implementation, and other criteria, thereby causing the new design shown in Figure 1b. It was further refined to improve structural integrity and practicality, and then [a model was] 3-D printed as shown in Figure 1c."

The use of the word "vagueness" is thought to be one natural byproduct of the course. Students were provided with freedom to design and create what they thought to be the best solution. At the same time, the word highlights an inherent uncomfortableness with open-ended design that was difficult to quell considering the primary mode of communication was email. The student went on to comment about communication, saying

> "It must be stated that the Community Garden Project group faced serious difficulty in having any meaningful channel of communication with the personnel responsible for the managing and operations of the garden. All members of the group visited the garden at

some point, and also sending [sic] email trying to create that channel of communication, but these efforts were futile. Seeing that it was an objective for the different groups to get feedback from which ever audience their project was geared towards, that channel of communication needs to be assured for each group to make sure of the effectiveness of each individual project. As a member of the Community Garden Project group it was a frustrating and confusing situation."
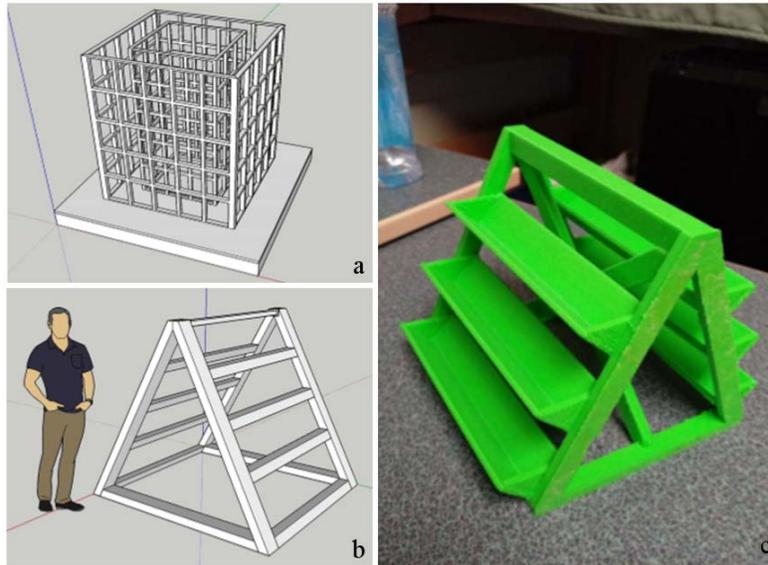

Figure 1: Example of project design and deliverable for the pilot course. (1a) is the individual mock-up in CAD, (1b) is the group mock-up in CAD, (1c) is the 3D printed model

This student thought communication with an external community partner was required and this was a source of frustration for his group. But, these interactions were optional. Although a lot of class time was spent clarifying expectations, there seemed to be an issue with communication. Effort was invested in correcting for issues with communication as the course introduced Slack. As Slack was introduced in the Fall 2018 course, the channel architecture was used to provide the necessary balance between flexibility and organization in order to improve communication.

Leveraging Slack's channel infrastructure towards flexibility

To provide further context on how the flexibility of having channels for communication was leveraged in the engineering design context is reflected in how the design process was generally facilitated. Channels offered to users changed based on which phase of the course students were completing. Three phases were completed: 1. Individual design phase, 2. Group design phase, and 3. Fabrication phase. In the individual design phase, the course director offered Slack channels that helped students understand the problem, learn foundational skills, and familiarize themselves with the course. An #announcements channel was created where the director was able to update and clarify instructions in real-time. Once students began the group design phase, private channels were created on Slack that each included the course director, one student assistant, and the members of the group. Groups were encouraged to use Slack as their primary means for communication. Because student assistants and faculty were connected to the individual design group private channels, issues were able to be addressed easily. Slack also

allows the course director to designate specific words as flagged in order to receive a notification each time the word is used. For example, the words "help" and "confuse" instantly sent the course director a notification to assist the individual or group. Once students entered the fabrication phase, channels were started that focused on help with specific fabrication tools and methods. A channel was dedicated strictly to helping with 3D printing. In addition, channels were used during the fabrication phase to provide role specific help.

Figure 2a shows the design process used, highlighting the steps for the individual phase of the course. At the end of the individual design phase each individual person had metabolized the problem and searched for potential solutions.
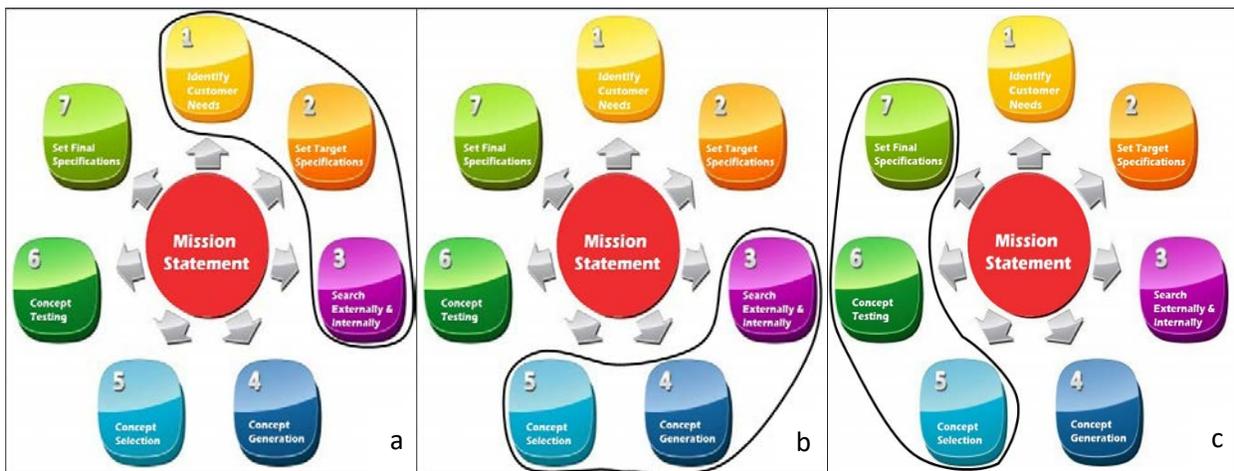

Figure 2: The design process used for the course. (2a) shows the steps for the individual phase (Step1. Identify Customer Needs, Step2. Set Target Specifications, Step3. Search Externally & Internally). (2b) shows steps for the group design phase (Step3. Search Externally & Internally, Step4. Concept Generation, Step5. Concept Selection). (2c) shows the steps for the fabrication phase (Step5. Concept Selection, Step6. Concept Testing, Step7. Set Target Specifications)

Students then received their design groups at the beginning of the group design phase. The channel structure shifted to provide each group with their own private channel in Slack. As part of the second phase of the course, groups begin by revisiting the search process for potential solutions. At the end of the group phase groups make a decision on what they would like to fabricate. Figure 2c shows the design process with the fabrication phase highlighted. Students entered the fabrication phase to develop a working prototype. Also, to begin the fabrication phase, groups adopted their individual roles and revisited the fabrication plans in light of their individual responsibilities on their teams. The design process concluded with a written paper at the end of the semester which detailed the final product specifications.

Leveraging Slack's channel infrastructure towards a concept map and organization

To communicate how Slack's channel structure was leveraged to provide the course with a knowledge map that helped students organize content, the example is provided of the course professional development module. Three Slack channels were created to help facilitate the development of students professionally. The college of engineering career consultant was invited to these channels to help address students career questions and concerns. The channels focused

on campus events, jobs opportunities and professional engineering student organizations. During one of the professional development assignments, students were tasked to attend a professional development workshop. With the use of Slack, students readily identified available activities on campus by visiting the Slack channels. All engineering student organizations were invited to join the professional development channels and each organization shared events as it pertains to their organization mission such as participation in robotic competitions, conducting industry information session, and networking events. Events posted on Slack were not limited to workshops but to scholarship announcements, jobs and internship opportunities as well. The channels were used to announce career fair, eminent research scholar seminars, graduate school info session, exam studying tips, technical skills development, resume building, and other related workshops offered on campus. The methodology used for this module was to teach students how to create an individual development plan (IDP); a customized roadmap that outlines career goals and professional training needed to accomplish those goals [32].

The IDP process guided students to reflect on their core competencies, desired skills and career aspirations. The course director was able to configure the Slack channels to provide the infrastructure needed to facilitate a comprehensive professional development experience. As a result, the course professional development module served as a starting place to enable students make the most of their undergraduate experience and to develop students with the skills to succeed beyond college. Slack channels allowed the course director to both provide a means to target the students based on what type of opportunity they were looking for and provide targeted resources towards professional development. A less restrictive implementation of Slack would provide users with the ability to create all of their own channels as they see fit. But, offering course director channels and monitoring those channels allowed for increased students support.

Challenges with Slack

Some issues were observed during the first semester with Slack. Effective social softwares should archive information effectively. Slack does archive information in a very useful way but restricts access to archived information when using the free version. Slack also has analytics to better understand how users engage with the software but this feature is also locked with the free version. When using the free version, the software caps the total messages at 10,000 messages and makes older messages inaccessible. During the Fall 2018 semester, the class reached the 10,000 message limit around week 8 or 9 of the course and ultimately sent over 30,000 messages. Important messages were not available to students once they entered the fabrication phase. Slack also provides access to files in a very intuitive way when the file is first posted. But, the free version of Slack also restricts the amount of cloud storage. Much like the message cap restriction, older files may not be accessible after the limit is reached. The class reached the storage limit around week 9 or 10 which was problematic. When students needed some particular files posted during the early weeks to help with fabrication these files were not accessible.

An additional challenge was related notifications and general use of the software. Both faculty and students voiced some resistance to using Slack. A channel was created that was dedicated to faculty only communication but some faculty preferred other means of communication. Official communication to faculty about the course was moved from Slack to email about midway through the semester. Students at times also avoided the modes of communication offered by

Slack. The software allows students to opt out of notifications and public channels were free to leave at any time. Freedom to interact and post content freely is one important characteristic of a useful social software. However, certain students were not seeing important posts by admins or the course director because they were opting out of notifications or leaving channels.

In addition, the course had some difficulty balancing content delivery between Slack and the traditional learning management system. For example, slide presentations were used to deliver course content both about assignments and project support. Therefore, slides were posted both to the learning management system and to Slack. However, this made it difficult when older presentations posted on Slack would be removed over time. Students did their best to resolve these issues by asking questions using Slack but the approach introduced some confusion.

Lastly, because Slack allowed users to post content freely, clarification was sometimes offered by student assistants that was wrong and had to be corrected. Slack provides for easy means of correction through either editing or deleting content. So, these types of issues were often corrected quickly, but a more restricted social software may have avoided the issue all together.

Changes in course and use of Slack for future semesters

After receiving feedback from students, a primary change enacted for the Spring 2019 semester was the use of Google Drive for posting course files. Although Slack allows for embedding content, the cloud storage limit makes using Slack exclusively for this purpose problematic. Slack also allows integration with other cloud storage platforms so by linking content to an external Google Drive account, much less content is posted directly through Slack to keep the workspace under the storage limit. The Google Drive also serves as an archive for important messages and information about the class. So, even if older messages are deleted, the most important ones are preserved on the class Google Drive. In addition, with the new system, course content can be made available to new students in future semesters.

Table 3: Strengths/weaknesses of Slack in comparison to integration of Slack used in the Fall 2018 semester and the integration used in the Spring 2019 semester

	Social software framework items 1-11 from Richards [13]										
	1	2	3	4	5	6	7	8	9	10	11
Slack	−	+			+	+	−	+	−	−	
Slack - Fall 2018	−	+	+	−	−	+	−	+	−	−	+
Slack - Spring 2019	+	+	+	−	−	+	−	+	+	−	+

Table 3 provides a comparison of the Slack implementation in the Fall 2018 semester and the Slack implementation for the Spring 2019 semester. The inclusion of the Google Drive implementation was done to improve items 1 and 9 from the Richards [13] framework. Item 1 is related to the importance of building a shared repository. In lieu of access to all information that would come with the paid version of Slack, Google Drive serves as a surrogate shared repository. To reduce frustration related to how best to find files when using multiple modes of communication, a "Materials and Tasks" page was created on the course website which linked to

all files, making them easy to find regardless of where they were initially posted. In addition, for class notes, a hard copy workbook was created for the students with PowerPoint presentations, resources, and worksheets printed hard copy. Page numbers from the workbook were also referenced in "Materials and Tasks". The use of the Google Drive also helped with item 9 which pertained to having an intuitive knowledge maintenance cycle. Using Google Drive helped easily update files of importance for everyone since one Google Drive was shared between all sections.

The last shift in how the course operates was related to the role of the course director. Most of the faculty from the Fall 2018 semester returned for the Spring 2019 semester. This allows for these returning faculty to teach both lectures for their course. This change was essential for the long-term success of the course.

Faculty reflections

Slack and EGN3000L are continually being improved. Two faculty provided a reflection on the use of Slack for EGN3000L which are provided for added perspective. Here is one faculty's reflection on using Slack in the course

"In the Computer Science environment, it is typical to facilitate instruction and learning through the use of software, so I had no issues with adopting Slack as part of the course. My understanding was that Slack was to be used, primarily by students, to handle and essentially organize any and all questions concerning the projects. I was encouraged by the fact that students would be able to use a communication tool that mimicked the kind of environment that they would use for a more recreational activity (such as Discord for gaming)."

"My observation however, was that students did not willingly use Slack as quickly and effectively as I had hoped. I suspect that the reason for this is due, in part, to the student's desire for instructor validation while taking this course. In a course like this, many students are intimidated by the 'student-lead' tasks and constantly sought approval from me before proceeding to the next task. I observed that even if a question was posted and answered correctly on Slack by one of the TAs, some students did not accept the answer unless it was confirmed by me or another instructor. It did not help that I viewed Slack as a more student-oriented platform and did not participate as often on it, preferring to leave the monitoring to the TAs for my section. Consequently, students would resort to more traditional means to maintain communication with me, such as in class, email, and through the learning management system. The addition of Slack now meant that I now had to navigate another platform while trying to address the students' needs. Additionally, the various means of communication meant that I was often answering the same questions across multiple platforms, which can be very frustrating, especially when there are technical difficulties!"

"After the course had ended, my colleagues and I realized the importance of establishing clarity regarding the course expectations, as well as enforcing the use of Slack early and often for handing project needs. We made changes to the course design on Canvas to better handle frequently asked questions, and restructured tasks so that they prioritized earlier project development. This has lead to a more comfortable communication experience, and has made it easier for me to monitor and participate on Slack. Despite the initial growing

pains, I now see Slack as very essential for maintaining consistency among the sections as well as providing guidelines for achieving the outcomes for the course. "

Another faculty member had a different experience as articulated in the following reflection

"The use of Slack in this engineering course helped facilitate learning outside of class and provided a means to monitor students learning outcomes. Slack provided a sense of community among students, teacher's assistants, faculty and other invited entities. The customized channels enabled continuous learning and dissemination of information beyond the classroom. I liked the student-to-student interactions, students who would not typically ask questions in class felt comfortable to do so on the forum. This forum helped clarify project questions and provided immediate feedback from the entire community as oppose to me responding to individual questions asked a number of times. Most often when I get a question that has been addressed on Slack, I would direct such students to the channel. This process of redirection helped foster the use of Slack and also provided a cohesive support system across the different course sections. Importantly, I have observed some peer-to-peer mentoring that has occurred on the platform, this by itself is encouraging as this builds students intrapersonal and interpersonal skills and also help hone the comprehension of the course content at-hand. Students could go on Slack at any hour of the day to get clarification on assignments, or get quick critique on their work. Based on my experience with this course, I strongly advocate implementing the use of social networking tools in other courses where engagement outside of the classroom would promote continuous learning and thus employ a key principle of learning taxonomies where in-class learning advances to higher order thinking.

For faculty members it was a platform that supported consistent delivery of instructional materials and the prompt broadcasting of information that would typically not be easily constructed in an email. Information such as highlights of previously taught session to "I am running late for the meeting" is an example of the way Slack was utilized among faculty. The ability for faculty to directly interact with students from other section also provided a different dimension of multiple streams of intellectual contributions. The only critique I encountered was that some students may have used Slack as a means not to read through the instructions on assignments and so, such students may have intentional use Slack as a crutch. One way to address this shortcoming is to redirect students to the learning management system where the instruction had being posted. Overall, I enjoyed using Slack for reinforcing pertinent information and facilitating progression of design projects".

Conclusion

An example freshman engineering design course is presented and discussed. Social software was used to address some challenges with collaboration. Slack offered many positive characteristics given in the literature for quality social software. Strategies for engineering design instruction that leverage technology in useful ways are useful for practitioners. This paper provides insight so similar tools might be used at other institutions in support of engineering design instruction. A similar approach might be necessary if a larger school seeks to provide project support to students but possesses limited resources. Some faculty reflections are provided to demonstrate the strengths and challenges as the course continues to evolve and added user perspective.

References

[1]   C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, "Engineering Design Thinking, Teaching, and Learning," *J. Eng. Educ.*, vol. 94, no. 1, pp. 103–120, 2005.

[2]   M. L. Martinez, G. Romero, J. J. Marquez, and J. M. Perez, "Integrating teams in multidisciplinary project based learning in mechanical engineering," in *Education Engineering (EDUCON), 2010 IEEE*, 2010, pp. 709–715.

[3]   N. Pan, H. Lau, and W. Lai, "Sharing e-Learning Innovation across Disciplines: an Encounter between Engineering and Teacher Education.," *Electron. J. E-Learn.*, vol. 8, no. 1, pp. 31–40, 2010.

[4]   R. Ubell, "Engineers turn to e-learning," *IEEE Spectr.*, vol. 37, no. 10, pp. 59–63, 2000.

[5]   L. Gilbert and V. Gale, *Principles of e-learning systems engineering*. Elsevier, 2007.

[6]   R. Bernsteiner, H. Ostermann, and R. Staudinger, "Facilitating E-learning with social software: Attitudes and usage from the student's point of view," *Int. J. Web-Based Learn. Teach. Technol. IJWLTT*, vol. 3, no. 3, pp. 16–33, 2008.

[7]   P. Resnick and R. Zeckhauser, "Trust among strangers in Internet transactions: Empirical analysis of eBay's reputation system," in *The Economics of the Internet and E-commerce*, Emerald Group Publishing Limited, 2002, pp. 127–157.

[8]   N. Sclater, "Web 2.0, personal learning environments, and the future of learning management systems," *Res. Bull.*, vol. 13, no. 13, pp. 1–13, 2008.

[9]   C. McLoughlin and M. Lee, "Social software and participatory learning: Pedagogical choices with technology affordances in the Web 2.0 era," 2007.

[10]   T. Bryant, "Social software in academia," *Educ. Q.*, 2006.

[11]   C. Dalsgaard, "Social software: E-learning beyond learning management systems," *Eur. J. Open Distance E-Learn.*, vol. 9, no. 2, 2006.

[12]   P. Baumgartner, "The Zen Art of Teaching," p. 19.

[13]   D. Richards, "A social software/Web 2.0 approach to collaborative knowledge engineering," *Inf. Sci.*, vol. 179, no. 15, pp. 2515–2523, 2009.

[14]   A. Tuhkala and T. Kärkkäinen, "Using Slack for computer-mediated communication to support higher education students' peer interactions during Master's thesis seminar," *Educ. Inf. Technol.*, vol. 23, pp. 2379–2397, 2018.

[15]   K. White, H. Grierson, and A. Wodehouse, "Using Slack for asynchronous communication in a global design project."

[16]   Slack, "Where work happens," *Slack*. [Online]. Available: https://slack.com/features. [Accessed: 02-Feb-2019].

[17]   B. Lin, A. Zagalsky, M.-A. Storey, and A. Serebrenik, "Why developers are slacking off: Understanding how software teams use slack," in *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion*, 2016, pp. 333–336.

[18]   L. Romkey, "Student-directed learning opportunities for the development of life-long learning skills," *Proc. Can. Eng. Educ. Assoc. CEEA*, 2012.

[19]   M. Gofine and S. Clark, "Integration of Slack, a cloud-based team collaboration application, into research coordination," *J. Innov. Health Inform.*, vol. 24, no. 2, pp. 252–254, 2017.

[20]   Y.-M. Huang, "Exploring students' acceptance of team messaging services: The roles of social presence and motivation," *Br. J. Educ. Technol.*, vol. 48, no. 4, pp. 1047–1061, 2017.

[21]   A. Van Deursen *et al.*, "A collaborative approach to teaching software architecture," in *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, 2017, pp. 591–596.

[22]   J. M. Perkel, "How scientists use Slack," *Nat. News*, vol. 541, no. 7635, p. 123, 2017.

[23]   X. Zhang, Y. Meng, P. O. de Pablos, and Y. Sun, "Learning analytics in collaborative learning supported by Slack: From the perspective of engagement," *Comput. Hum. Behav.*, 2017.

[24]   J. Chao, "Student Project Collaboration Using Wikis," in *20th Conference on Software Engineering Education Training (CSEET'07)*, 2007, pp. 255–261.

[25]   P. Thomas, D. King, and S. Minocha, "The effective use of a simple wiki to support collaborative learning activities," *Comput. Sci. Educ.*, vol. 19, no. 4, pp. 293–313, 2009.

[26]   S. Cochrane, L. Brodie, and G. Pendlebury, "Successful use of a wiki to facilitate virtual team work in a problem-based learning environment," in *19th Annual Conference of the Australasian Association for Engineering Education: To Industry and Beyond; Proceedings of the*, 2008, p. 429.

[27]   I. Blau and A. Caspi, "What type of collaboration helps? Psychological ownership, perceived learning and outcome quality of collaboration using Google Docs," in *Proceedings of the Chais conference on instructional technologies research*, 2009, vol. 12, pp. 48–55.

[28]   C.-C. Liu, S.-Y. Tao, W.-H. Chen, S. Y. Chen, and B.-J. Liu, "The effects of a Creative Commons approach on collaborative learning," *Behav. Inf. Technol.*, vol. 32, no. 1, pp. 37–51, 2013.

[29]   S. Mak, R. Williams, and J. Mackness, "Blogs and forums as communication and learning tools in a MOOC," in *Proceedings of the 7th International Conference on Networked Learning 2010*, 2010.

[30]   J. B. Williams and J. S. Jacobs, "Exploring the use of blogs as learning spaces in the higher education sector," *Australas. J. Educ. Technol.*, vol. 20, no. 2, pp. 232–247, 2004.

[31]   S. Glogoff, "Instructional blogging: Promoting interactivity, student-centered learning, and peer input," *Innov. J. Online Educ.*, vol. 1, no. 5, 2005.

[32]   SACNAS, "Building Your Individual Development Plan (IDP): A Guide for Undergraduate Students," *Medium*, 24-Jun-2017. .