

Scaffolding Project-Based Learning in an Engineering and Education Partnership using Open-Access Technology*

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This paper describes the use of a freely-accessible open-source platform based on Google Apps for Education that combines Google Sites, Google Docs, Google Drive, Google Hangouts and script language in a custom-based interface that supports collaborative service-learning projects for teams of Engineering and Education students. The approach discussed in this paper was successful in promoting collaboration among students from two different disciplines working remotely. The analysis suggests that balanced participation in the team, presence of shared goals and clear roles that emphasized individual and collective responsibilities were key to a successful interdisciplinary project experience. While many students still reported struggling with normal teamwork challenges, like finding common meeting times, others were pleased with the dynamics of their team and the opportunity to learn from one another. While SCOL, the open-source collaboration tool, did not significantly predict team satisfaction, the instructors found it very valuable for structuring project tasks, monitoring student progress, and providing timely feedback. The tool was seen as critical in supporting cross-disciplinary course collaboration for which students had limited access to face-to-face interaction. Faculty emphasized the importance of training students to use the asynchronous communication and collaboration tools (e.g., Google Docs and Google Hangouts) to maximize the benefits for students. Training will be included in future implementations of SCOL to ensure a more effective use of the platform.

Keywords: project-based learning; interdisciplinary teams; engineering education; collaboration technology

1. Introduction

Technologies that support work processes are of critical importance to the field of engineering as well as to the engineering classroom. More specifically, information, collaboration, and communication technologies (ICCT) are ubiquitous in engineering practice and universities as a vital element of the operations and the supporting infrastructure. These technologies facilitate collaboration and work accomplishment while also offering myriad opportunities to promote learning in academic environments.

Institutions of higher education have acknowledged the importance of preparing students to thrive in an environment that is increasingly global and highly reliant on technology. Future engineers must master critical professional skills such as the ability to work and communicate in teams using ICCTs. Teamwork and communication skills are broadly recognized as essential competencies required for successful professional practice in engineering [1, 2]. Project-based learning is a widely accepted pedagogy that facilitates the development of collaborative professional skills as well as technical skills. In engineering education, project-based approaches are especially relevant due to their alignment with the collaborative nature of engineering related work.

Although project-based collaborative learning holds great promise, there are some challenges that can limit its implementation in the engineering education environment [3, 4]. One common challenge is student resistance to participate in collaborative projects [4], where their grade depends on other students. A second challenge relates to the role of the instructor, who must expand from delivering lectures to facilitating collaboration. Instructors also face the challenge of designing projects and assessments that ensure student engagement, equitable participation, and fair grading [5, 6]. Prior research has pointed out the usefulness of learning scaffolds as a powerful enabler to successful collaborative work in project-based settings that can support both student learning and faculty teaching [4, 7, 8].

This paper describes how SCOL (Scaffolded Collaboration), an open-source platform, was used to structure and scaffold the team collaboration process between students in two academic disciplines. Engineering and education students collaborated in small cross-disciplinary teams as part of a project to develop and deliver engineering lessons to elementary school students. The project was part of a service-learning initiative to support a local school district through the early introduction of engineering into the elementary school curriculum.

Features	Trello	Asana	Slack	SCOL
Free access	✓	✗	✗	✓
Ability to include instructions and task lists	✓	✓	✗	✓
Collaboration space and repository	✓	✓	✗	✓
Provide individualized or group level feedback	✓	✗	✓	✓
Customizable	✓	✓	✓	✓
Secured access integrated into the IT system	✗	✗	✗	✓
Remote collaborative writing ability	✓	✗	✗	✓
Multiple levels of access and editing (user, observer, grader)	✓	✓	✗	✓
Replicable	✓	✗	✗	✓

Fig. 1. Comparative Analysis of Key Features in SCOL and other Collaboration Platforms.

There are a number of existing tools in the market that can support student collaboration, including but not limited to Trello, Asana, Slack, etc. Some tools such as Trello are free although not necessarily open-source, whereas Asana has only limited free features. Google Applications for education were selected for this project because they are already integrated into the information technology platform at the University where this study was conducted and many others in the United States. Additionally, access to this tool is authenticated and supported by the University Information Technology Department. SCOL is also highly customizable and replicable, and it allows for easy integration with Google Docs and Google Drive. The SCOL tool also provides the ability to grant diverse levels of access (viewing and editing) to multiple users including students, faculty, and teaching assistant. Fig. 1 compares key features in SCOL with those other commercially available collaboration tools.

Through the proposed study, engineering and education students collaborated in small cross-disciplinary teams as part of a project to develop and deliver engineering lessons to elementary school students. The project was part of a service learning initiative to support a local school district through the early introduction of engineering into the elementary school curriculum.

2. The SCOL platform

SCOL, a freely-accessible and open-source platform used to support collaboration, is built using Google Apps for Education and combines Google Sites, Google Docs, Google Hangouts, and script language to create a custom-based interface that supports project-based communication and collaboration processes for small teams of 4 to 10. The

platform includes several scaffolds that support the development and functioning of the team. Scaffolds were designed in the form of activities, embedded tools, and templates to be used throughout the project. These scaffolds are informed by research on high-performing teams and are used to structure and support key processes in successful collaboration such as goal alignment, planning, and communication [7–9]. Several empirical studies have documented the successful use of the SCOL platform in enhancing teamwork and developing skills in engineering students [4, 7, 8].

The standard SCOL interface includes seven elements: team member bios, a team name and mascot, a team charter, synchronous communication through web conferencing (Google hangouts), asynchronous text-based communication (discussion board), a file repository, and a calendar. Templates for specific activities (i.e., team building exercise) and deliverables (i.e., team charter) are pre-built into the tool and can be modified by instructors to facilitate project completion. The templates also increase transparency and traceability of project related activities and enable instructors to track the progress and completion of the activities. The platform was designed based on an in-depth literature review of best practices in student teams [7] (Pazos, Zhou & Magpili, 2017), which linked the collaborative processes seen in a successful team with the scaffolds in the open-source tool. An earlier and modified version of the tool has been previously used for teams of engineering students. The SCOL platform described builds on a previous tool (Pazos, Zhou & Magpili, 2017) that was modified to fit the multidisciplinary and service-based nature of this study. Fig. 2 outlines specific scaffolds that were built into SCOL and the corresponding collaborative processes that those elements were designed to support.

		Collaborative processes supported					
		Goal setting	Planning	Role Definition	Coordination	Backup Behavior	Monitoring progress
Features	Team Repositories		✓		✓	✓	✓
	Task Tracking		✓	✓	✓		✓
	Peer/Instructor Feedback				✓		✓
	Team Charter	✓	✓	✓	✓	✓	

Fig. 2. Elements of the SCOL open-source Platform designed to support Best Practices in Student Teamwork.

The first major activity for collaborating teams using SCOL is to create a team charter, or contract, where they document roles, expectations, and norms for the team. This activity requires each team to collectively answer a set of questions about their goals and expectations in a shared editable document. The result is a final contract that is signed and displayed in the collaboration tool throughout the length of the project. Fig. 3 illustrates a sample charter that includes team ground rules agreed on by members, roles and responsibilities of each team member, potential barriers and coping strategies, as well as member signatures documenting their commitment to fulfill the contract.

The SCOL platform also includes embedded video conferencing using Google Hangouts to facilitate synchronous communication through video and audio. This feature allows team members to meet without being in the same geographic location. The platform also includes a file repository built on Google Drive and other Google Applications that allows version control, team notifications, document tracking, and remote collaborative writing and editing. The repository has a prebuilt folder structure in Google Drive to organize different types of project documents. The repository provides appropriate levels of access to files to the team and instructor of record. Fig. 4 includes a screen capture of a sample team site that shows the task list and the project repository.

3. The Use of SCOL to support a cross-disciplinary collaboration

Prior research examined SCOL's effectiveness in facilitating teamwork for engineering courses at both the graduate and undergraduate levels [4, 7, 8]. In the current study, SCOL was used to support a cross-disciplinary collaboration between one section of a freshmen engineering course and two

sections of an education course for pre-service teachers. This investigation evaluates the usefulness of SCOL in supporting multidisciplinary teams of students in two courses from different disciplines and evaluates its ability to support project work from the perspective of the students and the course instructors.

SCOL was used to support engineering and education students as they worked in teams of 4–5 to develop and deliver engineering lessons to elementary school students following the 5Es format (Engage, Explore, Explain, Extend/Expand, Evaluate) [9]. Each team had its SCOL interface, which included scaffolds (team member bios, a team charter, and a file repository including required assignment templates) used to facilitate teamwork. Students had the option of selecting a team mascot or coming up with a team name. They were also encouraged to use the synchronous communication tool (Google Hangouts) embedded in SCOL for their meetings, but this was not required. Teams were required to meet at least three times and to submit the required assignments in the project repository. Additional project-specific assignments were added into SCOL using templates. For example, the engineering students filled out a literature review matrix that was later used by the education students to brainstorm on their own about the lesson plan, and both the engineering and education students completed the lesson plans together.

This paper will structure the results around the following three research questions addressing team collaboration and the use of the SCOL tool to support it:

1. How did the teams use SCOL to support their collaboration?
2. How did collaboration influence team satisfaction?
3. What are the perceived benefits and challenges of the cross-disciplinary collaboration from the perspective of the students and instructors?

TEAM GROUND RULES. Based on your prior discussion come up with an agreed upon set of rules		
How will the team communicate updates, meetings, etc.?		
The team will communicate... through phones via group chat.		
What is the maximum time to respond to communication by other team members?		
Team members should respond ...24 hours.		
How will you handle dissenting views in the team?		
Discuss it as a group and come to a solution.		
What kind of participation and level of commitment do you expect from each other?		
Everyone should participate and put in equal amount of work.		
How will team members share their contributions with the group? What internal group deadlines are you setting (e.g. when should team members post their contributions to the team lesson draft?)		
Whenever they get new information they should post it so others can see.		
What will happen if team members do not fulfill expectations?		
Their final peer review will reflect bad performance.		
Roles and Responsibilities. Assign key roles to each team member based to the work to be completed. The tasks listed are examples; you may change them to fit your team.		
TASK /ROLE	LEAD	CO-LEAD
Communications Manager: In charge of all group communications (making sure everyone stays informed) and communications with course instructors	Joseph	Mary
Lesson logistics and materials coordinator: In charge of acquiring needed materials for the lesson and planning the layout of the classroom space	Mary	Lu
Lead Researcher: Coordinating the effort to find information/resources for the lesson	Lu	Joseph
Lead Teacher & Lesson Editor: Ensures all lesson elements are completed and roles are designated for the implementation of the lesson	Joseph	Lu
Assignment Coordinator: Ensures all tasks and assignments are completed and submitted according to directions	Mary	Lu
Other:		
Potential Barriers and Coping Strategies: 1) What barriers to effective teamwork do you foresee in completing your team project and other team obligations? 2) How will you handle them if they materialize?		
Scheduling would be our main barrier, but we will be able to work it out via text messages to agree on times, and if we can't meet in person we will use google hangouts.		
SIGNATURES	DATE	
JOSEPH TAN	10/4/17	
Mary Mejia	10/4/17	
Lu Smith	10/5/17	

Fig. 3. Sample Contract (Charter).

4. Methodology

4.1 Participants

Seventeen teams participated in the service-learning project. The project was associated to two existing courses, one in engineering and one in education. Each team included both engineering and education students with three to six team members per team working on a common project that earned them credit towards their individual courses. A total of 87 college students participated in the research. The engineering students were predominantly first semester sophomores and male (95%). Education students were sophomore, junior, and seniors, and predominantly female (84%).

We used a concurrent triangulation mixed methods approach to study the effectiveness of the SCOL platform as a way to support cross-disciplinary collaboration. This study also evaluated how different aspects of the collaboration influenced team satisfaction and the overall collaborative experience.

4.2 Measures

We used a quantitative measure to assess the students' use of SCOL in support of project completion. Additionally, CATME, a survey-based instrument, was used to determine individual contribution to the team and satisfaction with the team experience [11].

A quantitative team-level analysis was conducted to evaluate the extent to which each team used SCOL and its features. Use of SCOL was evaluated using a 0–6.5 scale that measured the extent to which teams used the platform to support team building, develop a comprehensive team contract, share and contribute information, and overall use based on the log.

CATME, a web-based instrument developed to measure a range of team processes and outcomes [11], was given to students towards the end of the semester to assess their contribution and satisfaction with their teams. CATME uses self and peer evaluation of teammates' performance on a series of dimensions, including the ones used in this study

HOME
TEAM TASKS
TEAM MEMBER BIOS
TEAM CHARTER
PROJECT REPOSITORY

WELCOME TO YOUR TEAM SITE
 THIS SITE IS TO SUPPORT YOUR ENGINEERING LESSON PLAN PROJECT

28
 DAYS UNTIL LESSON DELIVERY

RECENT SITE ACTIVITY
[VIEW ALL](#)

TEAM TASKS

BELOW ARE THE TASKS THAT YOU WILL BE REQUIRED TO COMPLETE FOR THE TEAM PROJECT (LESSON DEVELOPMENT AND DELIVERY)

Title	Assigned To	LINK	Due Date
Sort	Sort	Sort	Sort
TEAM SIGN-UP	All students	SIGN UP SHEET WITH GROUP SIGNATURE	September 15, 2017
POST BIO ON GOOGLE SITE	All students	TEAM BIOS	
TEAM MEETING 1: CHARTER DEVELOPMENT AND MASCOT	Everyone in team must attend	ACCESS TO EXERCISES	
LITERATURE SUMMARY	Engineering Students	LITERATURE SUMMARY	
5E BRAINSTORM	Education Students	5E BRAINSTORM	
LESSON PLAN	All students	LESSON PLAN	
FEEDBACK TO PEERS	All students	LESSON PLAN	
DELIVER ENGINEERING LESSON	All Students		
LESSON REFLECTION - EDUCATION STUDENTS	Education Students	LESSON REFLECTION	
POST PROJECT SURVEY	All Students	SURVEY	
LESSON REFLECTION - ENGINEERING STUDENTS	Engineering Students		

PROJECT REPOSITORY

Fall18_Eng_Lessons_Team1

TITLE

- FALL 18 FEEDBACK FORM Dress Rehearsal Team 1
- FALL 18 TEAM 1 Lesson Draft
- Fall18_Eng_Lessons_Mascot_Team1
- Team 1 - 5E's Brainstorm
- TEAM 1 CHARTER FALL 18 ENG LESSON
- Team 1 Engineering Team Topic Literature Summary

Fig. 4. Sample screen capture of the collaborative tool home page.

(contributions to the team and satisfaction). Contribution to the team was evaluated using an eight-item Likert scale. Sample items include “the team member fulfilled the responsibilities to the team” and “the team member made significant contributions to the team’s final product”. Each team member earned a contribution score based on the average of his/her self and peer ratings. The average contribution was then calculated at the team level as the aggregate mean of individual contribution score by each of the team members. Satisfaction with the team was evaluated using a three-item 1–5 Likert scale. A sample item from this scale is “I am very satisfied with working in this team”. Satisfaction was calculated at the team level as an aggregate using the average of all team members’ satisfaction scores. Satisfaction is an important affective outcome in teams and it is considered a strong predictor of future engagement in team projects [12].

Individual student reflections were used a source of qualitative data. Each student wrote an individual reflection of approximately two pages about their experience with the team project. In particular, students were asked to describe what they learned regarding teamwork, and explain the perceived value of the overall experience, major challenges, and suggestions for improvement in the future. Student reflections were used to add depth to the findings exploring the influence of collaboration on team satisfaction, to identify plausible explanations for the role of the tool in supporting the team collaboration and project completion, and to illuminate perceived benefits and challenges to the collaboration process. Finally, the course instruc-

tors were asked to reflect on the challenges and benefits of the collaborative project in their courses.

4.3 Data analysis

The quantitative analysis examined, whether increased use of the collaboration platform and balanced contribution in the team were significant predictors of team satisfaction. We used linear regression analysis to build a predictive model of satisfaction with the team based on two variables: use of the collaboration tool and average contribution to the team. We tested whether the data fulfilled the assumptions of regression analysis. After transforming all variables into standardized z scores, the data met the assumptions of regression analysis, including linearity, normality, and multicollinearity.

The qualitative analysis was based on the individual student reflections at the end of the project. The researchers analyzed each reflection individually and then aggregated them by team for analysis. Grounded theory [13] was used to identify common themes related to collaboration processes and student satisfaction with the project.

5. Results and discussion

Results are structured around the three research questions and they integrate both quantitative and qualitative analysis and findings.

5.1 The role of SCOL in supporting teamwork

To look at use of the platform from the student perspective, we used a 0–6.5 point team rubric

assessing the following elements: completeness of the team member bios (1 pt), completeness of the team charter (2 pts), presence of a team name (0.5 pts), frequency of information exchange through the repository (2 pts), and balanced use of the tool based on the log (1 pt). Team scores ranged from 3.6 to 6.2, with an average score of 4.6. Tables 1–3 display a summary of team use of SCOL across each of the metrics.

Use of SCOL varied widely across teams, with some using it very sparsely, and a few using it extensively to collaborate and communicate. Use of SCOL also varied within members of the same team. In some, only a few members used the platform to collaborate, whereas other teams had very balanced participation. Although most teams met the basic assignment requirements for using the platform, very few used SCOL to collaborate beyond those requirements. Only two teams showed evidence of using SCOL extensively for sharing information and providing feedback to each other. The aggregate measure combining all the elements listed above was used to evaluate how the teams used SCOL and to determine whether the use of the platform influenced team satisfaction.

5.2 The role of the collaboration tool and collaboration processes on team satisfaction

Our second research question evaluated overall level of satisfaction with the team as a result of using the collaboration tool. Most individuals and teams reported high levels of satisfaction. The average individual satisfaction score was 4.22 ($N = 76$). Individual scores were aggregated to form a team satisfaction score. The average team satisfaction score was 4.20 ($N = 17$), with twelve teams averaging 4.0 or above (see Table 3). To evaluate the research question, we used a quantitative approach

through regression analysis to determine which factors associated with the collaboration were predictors of team satisfaction. Results of the regression analysis revealed that the two predictors explained 58.6% of the variance in satisfaction with the team ($R^2 = 0.58$, $F(3,15) = 5.66$, $p = 0.012$). It was found that average level of contribution to the team significantly predicted satisfaction ($\beta = 0.65$, $p = 0.01$) whereas use of the collaboration tool was not a significant predictor.

To provide additional insight into the factors that influenced students' perception as satisfactory or unsatisfactory, the researchers used a qualitative approach based on grounded theory [13], to analyze the student reflections from a sample of eight teams. Team satisfaction scores from CATME were used to identify four satisfied teams and four unsatisfied teams. Data from satisfied and dissatisfied teams were analyzed to identify common themes within each category. The following section describes the overall findings from the analysis.

When analyzing individual student reflections from four satisfied teams, several themes emerged. Students indicated that they had a fair workload balance, with each team member fulfilling their responsibilities with a common goal in mind. Further, members from satisfied teams reported that the students from both disciplines were willing to go beyond their perceived role and invest in aspects of the project where they had less expertise. One education student commented, "I am thankful to have been in a team with engineers who were so involved in the lesson. They actually wanted to teach the sixth graders and put effort into breaking down a somewhat complex lesson to where children could understand and learn." While many of the less satisfied teams described more rigid roles within their teams wherein the engineering students

Table 1. Use of SCOL by Team: Team Bios, Team Charter, and Team Name

	Student Bios (0–1pts for completeness)	Team Charter (0–2 pts for completeness)	Team Name (0 pt = missing, 0.5 pt = complete)
Complete	11 (65%)	13 (76%)	12 (71%)
Incomplete	6 (35%)	4 (24%)	0
Missing	0	0	5 (29%)
Mean Score	0.94	1.94	0.35

Table 2. Use of SCOL by Team: File Repository

	Frequency of Exchanges in File Repository
0–10 exchanges (0.5 pts)	10 (59%)
11–20 exchanges (1.0 pts)	5 (29%)
21–30 exchanges (1.5 pts)	1 (6%)
31+ exchanges (2.0 pts)	1 (6%)
Mean score (0–2 pts)	0.83

Table 3. Use of SCOL by Team: Balance of Use

	Balance in use (0–1 pt) 0pts = posts made by a single team member, 1pts = team members posted equitably
1.0	2 (12%)
0.7–0.9	3 (18%)
0.4–0.6	6 (35%)
0–0.3	6 (35%)
Mean Score	0.44

served as consultants, and the education students were solely responsible for teaching the lesson, satisfied teams described a more collaborative effort where students were willing to go outside of their comfort zones.

Analysis of the student reflections from the four least satisfied teams revealed that they struggled with several aspects of team collaboration. Issues seemed to stem from either a lack of understanding of the role that students were meant to play in the project or an unwillingness to step outside of rigidly defined roles. One education student commented, "I honestly believe the most challenging part of this entire experience was trying to collaborate with peers, who did not seem as enthused about teaching the lesson." Students in these teams cited concerns related to unbalanced workload and described team members who were unengaged in the process, resulting in other students having to fulfill the responsibilities of these team members.

The qualitative analysis provides insight into what led to higher levels of satisfaction. It reveals the role of balanced workload and participation, and also the importance of role clarity. These two aspects were found to be key to a successful collaborative experience. These findings reinforce existing literature that recommends faculty implementing collaborative projects to emphasize the importance of clarifying roles and responsibilities at the individual and collective level, and to ensure a balanced contribution of work that can be tracked transparently by students and faculty [4, 7, 8]. Prior research has also found that it is essential to implement assessments that reflect the consequences of not sharing the load of the project, and that those actions and consequences are documented and transparent to all team members [4, 7–9].

Successful approaches to supporting student collaboration in project-based learning include the use of charters to clearly describe and document roles and expectations, the use of project plans to outline all the individual and collective assignments and due dates, as well as the use of performance evaluation systems that measure fulfillment of individual and collective responsibilities that incorporate peer evaluation as part of the overall project performance score (grade) [4, 7–9]. SCOL can be customized to support all of these elements. In the engineering lesson project, only the team charter was fully integrated. In prior studies of project work support by SCOL, teams were asked to develop a comprehensive project plan with a list of all the activities, names of team members responsible to complete them, and deadlines. In this study, students were given a pre-created list of tasks instead of creating their own plan. The pre-made activity list likely reduced the workload for teams but may have also

reduced a sense of individual and shared responsibility for the activities.

Furthermore, students were largely unaware of how their contributions affected the overall project outcome and of how their teammates' felt about their contributions because these data were collected after the project was complete. Whereas in prior studies using SCOL 20% of students' final grade relied on peer evaluation, the peer evaluation scores in this study were only used to adjust student grades if they were particularly high or low. Future implementations will include using peer feedback through CATME earlier in the project so that group members (and instructors) can see their level of contribution, and can act if team members are not contributing at a satisfactory level.

The instructors elected not to fully utilize all of SCOL's features because the engineering lesson project was not the sole project in either class, and they were concerned about student workload. They acknowledge that the missing elements may have reduced the tool's effectiveness in supporting students' collaboration processes. They also offer several other plausible explanations for the absence of a correlation between SCOL use and student satisfaction. First, successful teams may have been efficient in their use of time. The instructors required teams to have three 1-hour meetings to complete the project, so teams that were successful may have been able to get all of their work done during those meetings without using the platform beyond those meetings. Second, some successful teams relied on alternative modes of communication not included in SCOL (e.g., group texts). SCOL was originally designed to support collaboration between students in distance learning courses who are not geographically collocated. In this project, all participating classes were held face-to-face, and many students did not see the value in using ICCT to support academic collaborations when they could meet on campus instead and use more direct modes of communication such as group text. One instructor observed that her students often delayed decisions until all group members could meet in person and did not make effective use of collaborative writing tools (e.g., Google Docs). A third explanation relates to the CATME instrument. The instructors noticed that students whose contribution was rated low often reported higher levels of satisfaction with the team than students with higher levels of contribution. This result suggests that students who contributed less were often more satisfied with their team than students who contributed more. This tendency may have artificially inflated overall team satisfaction for teams with low performing members.

The instructors are considering four actions to

improve workload balance and role clarity, and ensure effective and efficient use of SCOL. First, the instructors plan to discuss the research on collaboration in their classes to help students understand the need for a team charter that clearly outlines rules and responsibilities. This may help students view the activity as a worthwhile investment in their team's success rather than as just another task to complete. Second, the instructors plan to provide more clarity in the descriptions of the roles and responsibilities for each participating discipline and to include such verbiage into the team charter that all students must sign. Third, they will dedicate class time to training students how to use the tools embedded into SCOL, specifically Google Drive and Google Hangouts, to facilitate asynchronous collaboration. Finally, they will add a mid-semester team evaluation using CATME to provide team members with the opportunity to give and receive feedback on their performance while there is still time to adjust their behaviors.

5.3 Major benefits and challenges of the interdisciplinary collaboration experience

We also looked at benefits and challenges from the student and instructor perspective using a qualitative approach. The student perspective was evaluated through the individual student reflections. Instructors also provided insight into their experience by reflecting on the benefits and challenges from their perspective.

When reflecting on their experience collaborating in a team, students named several benefits. One of these benefits was the experience of working in a team that included another discipline. An engineering student commented, "The valuable aspect of this experience was that of working alongside other students of different discipline and making the lesson successful." Both the education students and the engineering students cited a second benefit of gaining knowledge and appreciation of another discipline. An engineering student commented, "I found value and appreciation in the teaching department, and what they do, it was nice to have a project that brought both engineering and teaching students to the same playing field." Students noted a final benefit of the experience as being a type of preparation for collaboration in their future careers. For education students, they viewed the experience as an opportunity to try out consulting a professional (i.e., an engineer) when teaching lessons outside of their scope of expertise. For engineering students, they viewed the experience as preparation for collaboration with other engineers as well as explaining complex concepts to other future associates.

Engineering and education students cited several

challenges to collaboration. Some noted that being able to communicate with other team members was the most challenging aspect of the experience. Some students reported scheduling conflicts when attempting to plan in-person meetings. Another frequently cited challenge was an unbalanced workload among team members and unengaged team members. An education student commented, "Working with other people is fine, when they know the end goal and are on the same page. I felt very unorganized and upset despite my efforts to push how important it was to get this done." Unengaged team members also proved to be a challenge for many students. Some students indicated that their teams struggled with issues integrating with another discipline. An engineering student stated, "I think our personalities were not compatible . . . it caused a lot of errors."

5.4 Instructor reflections on the collaboration experience

The instructors identified three benefits as a result of using SCOL: support in project structuring, ability to track and monitor teams, and ability to provide team feedback. The instructors believed that the decision to use SCOL foregrounded the importance of scaffolding the collaboration process within the project. They acknowledged previously assigning team projects without teaching students to collaborate or providing structures to support their collaboration process. Using SCOL required the instructors to deliberately structure the project to include team-building activities and to make sure teams clearly define responsibilities and deadlines. Furthermore, SCOL created an ongoing and permanent record of each team's project activities facilitating oversight and enabled the instructors and other interested parties to provide feedback to the teams as they progressed through the project.

5.4.1 Project structuring

Templates within SCOL were carefully developed to include assignments that needed to be completed as an individual (e.g., the bio) or by the entire team (e.g., team charter and lesson plan), as well as those by the engineering students (e.g., literature review matrix) or the pre-service teachers (e.g., 5 E's brainstorm). One example of this is that the engineering students filled out a literature review matrix, and provided sources of 5 articles they thought would help in the lesson planning. Specifically, this literature review required the students to identify which "E" (Engage, Explore, Explain, Extend/Expand, Evaluate) the article related to, briefly summarize the content, and indicate how they thought the source could contribute to the "E" that was identified. The education students in turn used the litera-

ture review matrices completed by the engineering students to brainstorm lesson activities that corresponded to each of the 5Es (for example, a video to help “explain” relevant science concepts). Such interdependent assignments allowed the two teams of students to build off each other’s work and divide the responsibility of the project. After both teams worked individually on the project, the engineering and education students worked together to draft their lesson plan, test it out on a group of their peers, and deliver the final lesson to elementary school students.

5.4.2 Team monitoring and team feedback

Two class sections taught at different days and times by two instructors were included in this project. The instructors saw project oversight, team monitoring, and coordination as a formidable challenge. They noted that SCOL can be used to provide an objective account of team member contribution since instructors, teaching assistants, and all team members have direct access to all team members’ contributions through the project repository and Google Docs and Google Drive logs. This was seen as a benefit because traditional course management systems (e.g., Blackboard) do not offer this level of access. The common repository and incorporation of Google Docs also enabled all participants and other stakeholders (e.g., faculty recruited to observe the students’ dress rehearsals) to provide direct feedback to the team. The platform can also be used to evaluate individual contributions and team deliverables.

6. Conclusion

The approach to project-based work discussed in this paper was successful in promoting collaboration among students from two different disciplines. Seventeen teams of engineering and education students successfully delivered engineering lessons to over 150 6th grade students using an open-source platform to facilitate the cross-disciplinary collaboration. The analysis suggests that balanced participation in the team, presence of shared goals and clear roles that emphasized individual and collective responsibilities were key to a successful interdisciplinary project experience. While many students still reported struggling with normal teamwork challenges, like finding common meeting times, others were pleased with the dynamics of their team and the opportunity to learn from one

another. While SCOL, the open-source collaboration tool, did not significantly predict team satisfaction, the instructors found it valuable for structuring their project, monitoring student progress, and providing feedback, especially in the context of cross-disciplinary course collaboration. They emphasize the importance of training students to use the asynchronous communication and collaboration tools (e.g., Google Docs and Google Hangouts) embedded SCOL to maximize the benefits for students. Training will be included in future implementations of SCOL to ensure a more effective use of the platform.

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