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ENHANCING STUDENT COLLABORATION FOR IMPROVED LEARNING

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Synopsis:

In a traditional class, students interact primarily with the instructor. Increasing the level of student interaction with one another during the learning experience provides a significant multiplier in the student learning experience. Instead of all learning occurring on the student-instructor axis, learning occurs on multiple axes between students. Getting students to interact meaningfully with each other is an important result of student collaboration. During this academic year, we have conducted research on collaboration with student mentors and in small groups. Results are presented, including analysis of surveys of students along with instructors' experiences.

Enhancing Student Collaboration for Improved Learning

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ABSTRACT

Information is increasing at a dramatic pace. The ability of the learner to absorb this increase and create knowledge requires that learning take place at an accelerated pace. We have focused on expanding student collaboration to create a student learning environment that enhances accelerated learning and strengthens the ability to retain what has been learned.

It is particularly critical in an accelerated learning environment that a significant amount of the learning experience comes from students' interactions with each other. In a traditional class, students interact primarily with the instructor. Increasing the level of student interaction with one another during the learning experience provides a significant multiplier in the student learning experience. Instead of all learning occurring on the student-instructor axis, learning occurs on multiple axes between students. For example, if each student has high quality interactions with four other students during a course, there is the potential to increase student learning by as much as a factor of five.

Getting students to interact meaningfully with each other is an important result of student collaboration. We have experimented with and used a number of mechanisms for enhancing student learning, including interactive exercises with tablet computers in both onsite and online classes. Recently, one of the authors implemented small group student presentations of a group-generated mp4 recording of their analysis of a series of ethical dilemmas, along with their conclusions and recommendations, in a Computer Ethics class and in classes on computer and network security.

During this academic year, we have conducted research on collaboration with student mentors and in small groups. In the former, students mentor each other on their submissions, and suggest improvements to each other's work. With small groups, each student reviews and suggests improvements to the work of all members of the group. Their final products are the result of several iterations of this process. Results are presented, including analysis of surveys of students along with instructors' experiences.

INTRODUCTION

In a 2011 article, Lucas Mearian commented, "the world's technological information-processing capacities are growing at exponential rates." (Mearian, 2011). He noted that more than 295 exabytes of data has been stored since 1986. (1 exabyte = 10^{21} bytes) An earlier study noted that "new stored information grew about 30% a year between 1999 and 2002". (How Much Information?, 2003) The study noted that the combination of "print, film, magnetic, and optical storage media produced about 5 exabytes of new information in 2002," and estimated that this was "equivalent in size to the information contained in 37,000 new libraries the size of the Library of Congress book collections." The same 2002 study estimated that 18 exabytes of new information were being generated annually by electronic flows. On Nov 11, 2016, WorldWideWebSize.com estimated that the indexed web contains at least 5.02 billion pages. (WorldWideWebsize.com,

2016) Of course no individual can absorb more than a very small amount of this information. Nevertheless, the amount that must be learned in any field is rapidly expanding, and this argues for an accelerated learning environment for students.

In a traditional class, students interact primarily with the instructor. Increasing the level of student interactions with each other during the learning experience can provide a significant multiplier, accelerating the student learning experience. Instead of learning occurring on the student-instructor axis, learning occurs on multiple axes between students as well as between students and instructor. Matthews (1996) notes "Collaborative learning occurs when students and faculty work together to create knowledge. . . . It is a pedagogy that has at its center the assumption that people make meaning together and that the process enriches and enlarges them" (Matthews, 1996, p. 101).

There is substantial evidence that the use of student collaboration in small groups can accelerate both academic achievement and learning, when it is used to supplement traditional teaching approaches using lectures and classroom discussion. Springer, Stanne, and Donovan (1999) noted that, "Students who learn in small groups generally demonstrate greater academic achievement . . . than their more traditionally taught counterparts. The reported effects are relatively large in research on educational innovation and have a great deal of practical significance" (Springer et al., 1999, p. 42). Barkley, Major and Cross (2014) comment, "While cognitive gains are important, in higher education we have seen increasing emphasis on the development of higher-order thinking skills. Research suggests that there is a correlation between participation in collaborative learning and gains in these skills." Student collaboration also causes learning to move to a higher level in Bloom's taxonomy of learning (Bloom et al, 1956), as student's engagement increases, resulting in higher levels of critical thinking.

Enhanced student engagement and establishing a sense of community are important outcomes of student collaboration; these can be achieved in an online environment as well as in onsite classes. Dixson (2010) found that strong methodology and opportunities for students to interact with each other and the instructor are required in online classes, and she noted that the effectiveness of using collaborative activities, group discussions, and other forms of student-student interaction is one of the recurrent themes in the literature. She notes that group projects are one of the types of active learning in online courses that students report as engaging. She urges that "instructors should consider assignments in which students interact with each other and the content of the course. Instructors need to create not just opportunities for students to interact, but the requirement that they do so. Students who are working on group projects together, doing peer review of one another's papers, interacting within a discussion forum on a particular topic, are likely to feel more engaged in the course."

Sarder (2014) notes that establishing a sense of community within an online course is an effective way to engage students. He explains that "Community, in the online sense, can be defined as an environment which is enabled through the interaction and collaboration of its members using various technology and mixed media methods," and "interaction is the essential building block of any community. If members of a community are not able to interact in some form or fashion then it does not exist."

Young and Bruce (2011) note that "Classroom community and student engagement are closely related to one another. Students who feel a sense of connectedness and psychological closeness rather than isolation are better prepared to become more actively involved with online

learning and the resulting higher order thinking and knowledge building." They continue with, "Collaborative learning experiences online can increase participation and connectedness by means of enhanced critical thinking, shared reflections, and helpful feedback among peers within the relatively safe context of anonymity." They posit that a successful online learning community encompasses two underlying dimensions: learning, which relates to academic content, and social, whereby students feel a personal involvement with others. Finally, they note that small group activities are one of seven ways in which online community can be enhanced.

The authors have put particular emphasis on hands-on activities. Harrington and Floyd (2012) state that, "Hands-on activities may be described as "active learning," which is the opposite of "passive learning," in which one-way communication from teachers to students is the norm. Active learning involves substantive changes in the ways students and teachers work together, shifting the focus of classroom instruction to student activities such as gathering, analyzing, and presenting data; defining issues; and drawing and defending conclusions. The aim is to create independent and engaged learners." They also note that "Hands-on learning activities increase student engagement and heighten perceived course value," and "Student engagement is evident when students demonstrate prolonged attention to a mentally challenging task, resulting in authentic learning and increased levels of higher-order thinking."

Zappala (2012) commented that, "Students who actively participate in the learning process learn more than those who do not.", and he remarked that, "Other ways to help assess students' thinking included…Having each student present course concepts to a small group of three or four other students."

Some of the authors have published findings on increasing student engagement in engineering classes through interactive exercises with tablets, (Uhlig, R., Farahani, A., & Viswanathan, S., 2011), and through use of student designed and developed games (Jaurez, J., Fu, P., Uhlig, R., & Viswanathan, S., 2010). This paper focuses on student collaboration to enhance learning and the learning experience.

THE CHALLENGE OF SMALL GROUPS IN ONLINE CLASSES

Businesses that hire our graduates expect them to have the skills to work together in small groups, because much of the work done in engineering organizations is done in small groups. Our Institutional Learning Outcomes and our Student Outcomes, require that students are able to work together effectively in teams. As a result, a requirement to work on one or a few projects in teams of 3 or 4 persons has been a component of a number of onsite courses for many years. But, this approach has been problematic in online classes. The requirement has usually been implemented in online courses by requiring that small groups present their results in a synchronous online session using Blackboard Collaborate.

The requirement to participate in "live" presentations created an obstacle for some students, for example for a student whose job required working in the evening. To address this issue, we revised the process for small group presentations, to enable groups to create an mp4 video streaming presentation by narrating PowerPoint charts which are then "exported" as an mp4 file which is then posted to the online class for all to view. Members of the group are not required to meet simultaneously to prepare and produce the mp4 presentation, although some may choose to do so. This approach allows all online students to be part of their small group's presentation, whether or not they can participate in synchronous class sessions.

Groups are invited to narrate voice annotated MS PowerPoint™ charts, as follows:

"Each member of each group is expected to record their voice presentation for AT LEAST two PowerPoint charts developed by that group member, using the PowerPoint "Insert Audio" command (2nd from the right under the "Insert" Command, as shown below) and pull down to the "Record Audio" option on the menu.

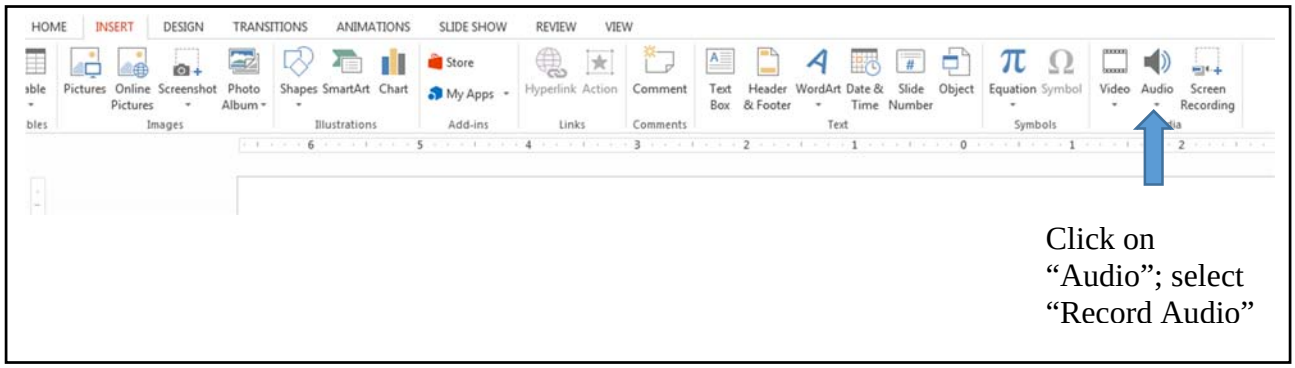

Figure 1 - Use of the MS PowerPoint Insert Audio Command

These mechanics are simple and easy to understand. The instructor does a simple "walk through" during an early Collaborate session, explaining how to insert voice annotation on a chart as shown in Figure 1. An mp4 streaming video explaining the process is also made available for all students. The requirement that each member of the group prepares at least two charts is easily enforced by asking students to place their initials somewhere on the chart, and because most student's voices are distinct and easily recognizable.

Group members are also encouraged to post their charts in the Blackboard Group File Exchange, as their presentation develops, because voice annotation of charts often makes the PowerPoint files too large to exchange using email, but much of the discussion of the charts takes place using email. Some groups have chosen to interact using Google Hangouts.

The process of converting a "final" set of voice annotated charts to an mp4 presentation is straightforward, using the "Export" command under the "File" tab in PowerPoint. The resulting mp4 file is submitted to the instructor, who then posts it for the whole class to view. Finally, each member of the class is required to comment in some depth in threaded discussion about whether they agree with the findings and conclusions of at least one group other than their own.

This approach, which was first implemented in the 2015-16 academic year, produced some unexpected dividends, resulting in small group presentations that were better than "live" presentations during scheduled Collaborate sessions. The recorded presentations sometimes even turned out to be more polished, than comparable small group presentations in on site classes. These results have been discussed by Uhlig (2016).

EXTENDING STUDENT COLLABORATION IN SMALL GROUPS

Encouraged by the results discussed above, the requirement for collaboration was extended in several classes during the 2016-17 Academic Year, to encompass group collaboration and individual writing assignments. To increase group collaboration in small group projects, a Teamwork element was added to the Grading Rubric, formally requiring team members to provide constructive suggestions for improvement on each other's work. Students were asked to use the Blackboard Group Blog to enter their comments. The instructor reviewed and graded these comments as specified in the rubric. To increase collaboration on writing assignments, students were required to mentor each other, by reviewing drafts of student papers before they were submitted and providing constructive suggestions for improvement.

An extensive set of instructions was developed to explain how the small groups were to operate. This started with explaining that the reason for this expansion was to strengthen the process of students learning from each other, and the approach was backed up with several research findings. Reasons why business makes such extensive use of small groups were discussed, including sharing of knowledge, maximizing benefits of diverse experiences, creation of new ideas through group discussion, checks and balances that come from teamwork, and mutual support to increase productivity. This was followed by a brief exploration of advocacy as a contest to be won versus problem solving by a group through inquiry. Small groups were encouraged to operate from the perspective of inquiry rather than advocacy.

Step	Explanation	Timing
1	Agree on Team Coordinator for each project	Day 1
2	Generate proposed solution(s)	Day 1
3	Decide who will work on what	Day 1
4	Spend time **individually** researching relevant facts	Days 2-3
5	Individually generate PowerPoint charts with your initials and narration	Days 2-3
6	Post charts to Blackboard Group File Exchange	Day 4
7	**Every** team member **reviews** draft charts & posts constructive comments	Days 4-6
8	Individuals revise charts and resubmit	Days 4-6
9	Repeat steps 7-8 as required	
10	Team Coordinator export result to mp4 and submit	Day 7

Table 1 – Suggested Steps for Group Projects

Groups were encouraged to have a short ten-to-fifteen minute first meeting in which they introduced themselves to one another, shared strengths and weaknesses of group efforts in which they had been involved with current or previous employers, and, finally, to agree on ground rules for their group interactions during the project. This was followed with a set of suggested steps as shown in Table 1.

In their initial meeting, the small groups were asked to agree on the coordinator who would be responsible for collecting charts from all team members and posting them at the end of the project. They were also asked to brainstorm to come up with one or more proposed solutions or approaches, and then divide up the work among themselves. Members of the group were then advised to do their research first to come up with facts and ideas, and then develop their initial draft charts on the second and third days of the project. Then, the schedule called for them to post their charts in the Group File Exchange for review and comment by all team members. Depending on constructive comments by fellow team members, they might go through steps 7 and 8 several times before they were satisfied. Finally, the team coordinator would assemble the final set of narrated charts and export it to an mp4 streaming video file, using PowerPoint.

To make it possible for small groups to meet simultaneously for Steps 1-3, if they wish, the course Blackboard Collaborate session has been set up as one long session that is available for all members of the class throughout the duration of the course, with every member of the class having moderator privileges, and breakout rooms have been provided for each of the groups. This means that small groups can agree to meet "live" any time they choose, without asking the instructor to set up a special meeting place/time for them. If two small groups decide to meet at the same time, they can use the breakout rooms to keep from interfering with each other. It is usually possible for three or four persons in a group to find a time when they can meet simultaneously, although large time zone differences can occasionally make it difficult for some.

Appendix A shows the grading rubric used for small group projects. A few changes have been made to the rubric reported in Uhlig (2016). "Teamwork" has been added as a new grading element, while "Thoroughness of Material" and Thoroughness of Sources have been combined into a single grading element entitled "Thoroughness of Work." Each grading element was given equal weight.

Barkley, Major and Cross (2014) comment, "Since achieving individual accountability while still promoting group interdependence is a primary condition for collaborative learning, it is most effective if grades reflect a combination of individual and group performance." In keeping with this recommendation, a decision was made to provide individual grades for three elements on the rubric: teamwork, quality of charts and quality of verbal presentation, while the other seven elements comprised the group grade. So, 30% of the grade on projects was based on work by each individual, while 70% of the grade was based on work by the group. While it may seem strange to grade the "teamwork" element on an individual basis, this provided a motivation for each individual team member to provide quality constructive comments on the work of their teammates. Each team member was asked to input their comments to the Blackboard Group Blog for review by the instructor, in awarding grades for each project.

ADDING STUDENT COLLABORATION TO WRITING ASSIGNMENTS

In addition to the ability to work in teams, today's employers demand graduates who are effective in both oral and written communications. The small group projects discussed above are focused more on oral communication, with some relatively informal writing. A second focus of our work has been on helping students to improve their writing skills through student collaboration. It can be difficult to coach engineering students to improve their writing skills. To address this issue, we added student collaboration to writing assignments, asking students to coach each other.

Our original plan was to have students exchange draft papers, to mentor each other on writing assignments. However, that scheme only works if there are an even number of students in

a class. In addition, we wanted to give an opportunity to students to receive suggestions for improvement from more than one student, so we instituted a process in which each student had two student reviewers for their draft paper. This was set by using an alphabetic listing of students by last names, and assigning the next two names alphabetically to be mentors for each student. The mentor listing simply wrapped around to the first names in the alphabet for the last two students in the list. This approach works whether the number of students in a particular class is odd or even. Each student reviewed two draft papers written by other students and each student had two reviewers for their own drafts. Student reviewers were asked to make constructive suggestions for improvement. Details of the process are shown in Table 2.

Step	Explanation	Timing
1	Prepare first draft of paper	Days 1-4
2	Email draft to assigned mentors	Day 4
3	Mentors suggest improvements	Day 5-8
4	Originator incorporates suggestions they accept	Days 9-13
5	Original student submits final paper	Days 14

Table 2 – Suggested Steps for Mentoring of Writing Assignments

The first writing assignment in a master's level class on Security in Computing was taken from the textbook for the course. It was as follows:

> "Outline the design of an authentication scheme that "learns." The authentication scheme would start with certain primitive information about a user, such as name and password. As the use of the computing system continued, the authentication system would gather such information as commonly used programming languages; dates, times, and lengths of computing sessions; and use of distinctive resources. The authentication challenges would become more individualized as the system learned more information about the user.
>
> Your design should include a list of many pieces of information about a user that the system could collect. It is permissible for the system to ask an authenticated user for certain additional information, such as a favorite book, to use in subsequent challenges.
>
> Your design should also consider the problem of presenting and validating these challenges: Does the would-be user answer a true-false or a multiple-choice question? Does the system interpret natural language prose?" (Pfleeger, C. P., Pfleeger, S.L. and Margulies, J., 2015)

This assignment was substantive, requiring significant thought and analysis by the student, and requiring them to integrate multiple concepts to show mastery. As shown in Table 2, they were given four days to prepare a first draft, which they then emailed to their mentors. The mentors then had four days to review the two papers they received and to suggest improvements. Because all students worked on the same assignment, they were free to incorporate ideas in their own paper from papers of students they were mentoring, but not to copy their words verbatim. They were instructed to make constructive suggestions for improvement of the paper; not to simply criticize. Mentors were required to copy the instructor, when they emailed their suggestions for

improvement to the originator. The originator then had the option of incorporating some or all of the suggestions for improvement into their paper. They were under no obligation to do so, and had to evaluate whether or not they wanted to suggest improvements.

The rubric for grading writing assignments is shown in Appendix B. It has only 8 grading elements – two fewer than the rubric for grading small group projects in Appendix A. The final grading element in Appendix B is for the suggestions for improvement provided by students for the two other students they mentored. It has both a quantitative aspect, i.e. number of comments made, and a qualitative aspect, i.e. is it a true suggestion for improvement or merely a general comment. A second writing assignment in the same class was not mentored. In part, this was because the second assignment was more of a problem requiring mathematical calculations, and in part it was to give students an opportunity to reflect on whether the mentoring process for their first assignment helped them.

RESULTS AND FINDINGS

Results were positive for both the collaborative writing assignments and for the small group projects, although there were some concerns. The collaborative writing assignments will be discussed first, followed by discussion of results of the small group projects. Finally, results of a survey of students regarding their collaborative learning experience will be discussed.

Mentored Individual Writing Assignments

The identical writing assignment had been completed in a January 2016 onsite master's degree class in cybersecurity by 15 electrical engineering students, but the mentoring concept was not used in that class, because the concept had not yet been formulated. The 20 students who completed the mentored assignment in the December 2016 online class did a better job on this assignment than students who completed the identical assignment in the January 2016 class. This assessment of "better job" is a qualitative judgement, but it is also based on a comparison of specific elements of the rubric which was used in grading each student's assignment in each class. Both sets of students received identical instruction in the basics of authentication and access control prior to beginning the assignment.

The average grade for the 15 students who completed the assignment in the January 2016 class was 86.4%. The median grade was just slightly higher at 87.0%. The standard deviation was 4.8%. Grades ranged from 73.4% to 93.0%. The average grade for the 20 students who completed the assignment in the December 2016 class was 88.4%. The median grade was higher at 90.5%. The standard deviation was 10%. As implied by the larger standard deviation for this class, the range of grades was wider, from a low of 71.3% to a high of 100%. Although the average grade for the December 2016 class is 2% greater, the standard deviation is large enough for both classes that it would be impossible to judge which class performed "better" on the assignment on the basis of grade averages. A t-Test analysis showed no statistically significant difference between the grade distributions on this assignment for the two classes.

A closer look at the individual grading elements shows a significant difference between the two classes in the distributions of the assessments of the first four elements of the grading rubric: Quality of Research, Original Thinking, Understanding of the Subject, and Thoroughness of Sources. Figure 2 shows the distribution of grades for these elements of the rubric in the two classes. The class with mentoring shows a distinct shift towards better papers for the December 2016 class. The January 2016 class peaks around "Commendable" while the December 2016 class

peaks in the "Outstanding category. A significant number of students moved from "Commendable and "Very Commendable" into "Outstanding". These are the four grading elements that the authors expected to be the most improved by the mentoring process. The categories of "Organization", "Effectiveness of Conclusions", and "Thoroughness of Work" were less susceptible to improvement by the mentoring process, and the final category, "Quality of Comments to Mentored Students" was not part of the rubric for the January 2016 class.

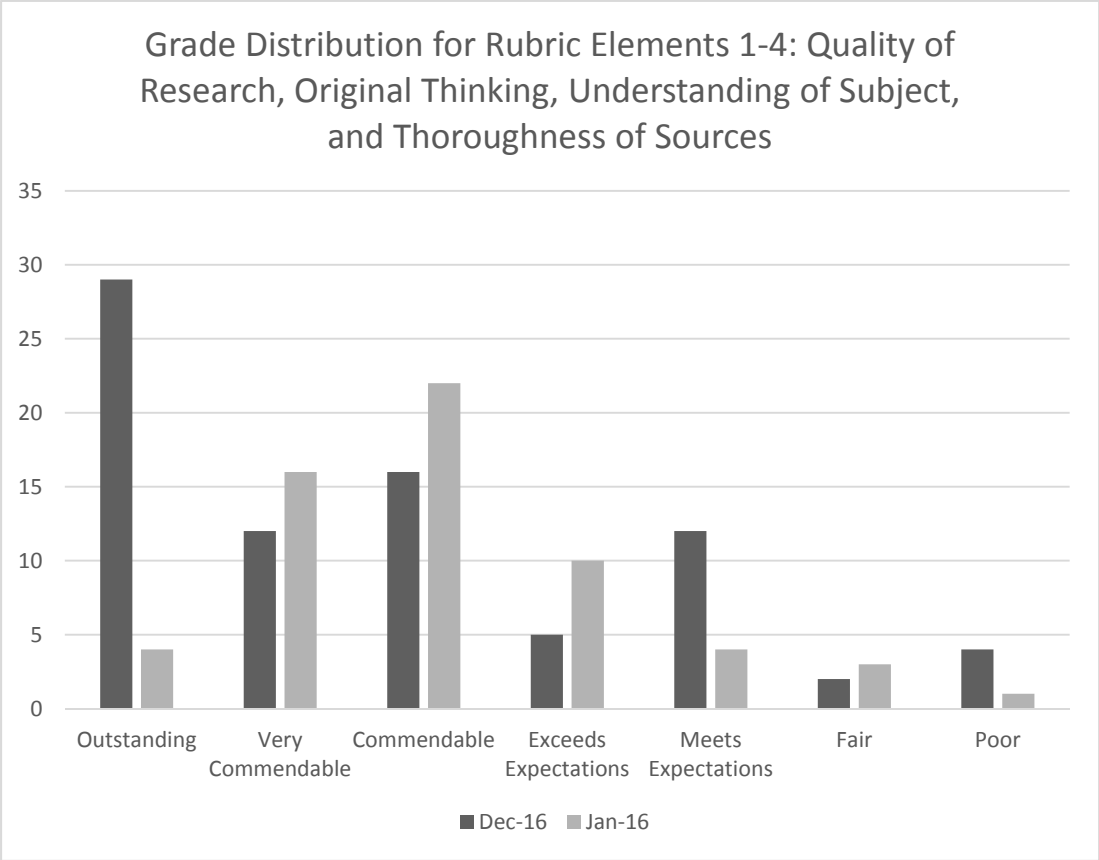

Figure 2 – Mentored Assignment Rubric Element Distributions for January and December Cybersecurity Classes

A few words of caution are in order. This initial evidence indicates that the mentoring process is effective. However, it was not effective for every student. Students were given two weeks to complete the assignment. It was suggested that they send a first draft of their paper to their mentors by the end of the fourth day after receiving the assignment. Their mentors then had four days to respond with their comments and suggestions for improvement. Finally, the originator of the draft had four more days to complete their paper and submit it. They were under no obligation to accept the comments and suggestions from their mentors. The instructor was copied on all comments provided, and there were many excellent comments and suggestions.

Students who were well organized followed the process fairly well, but some students waited until nearly the end of the two weeks to even send a draft to their mentors. 15 students in the December 2016 class were graded Outstanding, Very Commendable, or Commendable on the comments they made to students they were mentoring. Only three students were graded Meets Expectations, Fair, or Poor" Two mentors did not have the time to comment meaningfully, when

papers for their review arrived very late. Habitual procrastinators may not derive much, if any benefit from the mentoring process.

Collaborative Small Group Projects

Small group size ranged from three persons to five persons in both the December 2016 class and the January 2016 class. Nine of ten small group projects in the online December 2016 class in cybersecurity were identical to the projects assigned in the on-site January 2016 class. However, in the January on-site class, most of the work done on the small group projects was done by students working together face-to-face in the classroom, while all work was done online in the December 2016 class. In the December class, students were asked to make written suggestions for improvement to each other using the Blackboard Group Blog, while there were no written suggestions for improvement in the January 2016 class.

The recorded presentations developed by project teams in the December class generally turned out to be more polished than live presentations in the January class, as a result of the process followed by the December small groups. The process of exchanging and reviewing their voice annotated charts with one another had the effect of causing students to rehearse and refine their part of their presentation. This led to self-reflection as well as improved quality in the final product.

Figure 3 shows a comparison of the distribution of last two grading elements in the rubric for small group presentations: "quality of charts" and "quality of verbal presentation". The distributions are similar to the distribution of grading elements for the mentored assignment, shown above in Figure 2. The distribution for the January 2016 class peaks about "Very Commendable, while the distribution for the December 2016 class has clearly shifted toward "outstanding, demonstrating the effectiveness of the process of developing recorded presentations for collaboration.

Overall grades for Small Group Projects were higher in the December 2016 class than in the January 2016 class, as shown in Table 3. A detailed t-Test two-sample analysis was done on the full set of small group project grades for January and December classes. The result showed a probability of less than 10^{-8} that the difference was **not** statistically significant.

In addition, the magnitude or size of impact quantification, referred to as Effect Size Cohen's d (also sometimes referred to as Standard Mean deviation or Standard Mean Effect) - was calculated as follows (Cohen 1988; Cohen 1992; Coe 2002):

$d = (A1 – A2)/s,$

Where A1 = Average of assessment score with collaboration (referred to as the Intervened)

A2 = Average of assessment score without collaboration (referred to as the Control group)

s = pooled standard deviation of assessments of both groups.

The Effect Size is expressed as a number of standard deviation units.

Calculating the Effect Size for the current analysis:

Effect Size for Projects 1-4 = 2.32 (Pooled Std Dev = 2.5)

Effect Size for Projects 5-9 = 0.78 (Pooled Std Dev = 3.1)

Effect Size for Cracking WEP Project = 1.31 (Pooled Std Dev = 2.2)

The aggregate effect size across all projects was 1.17 which is very large.

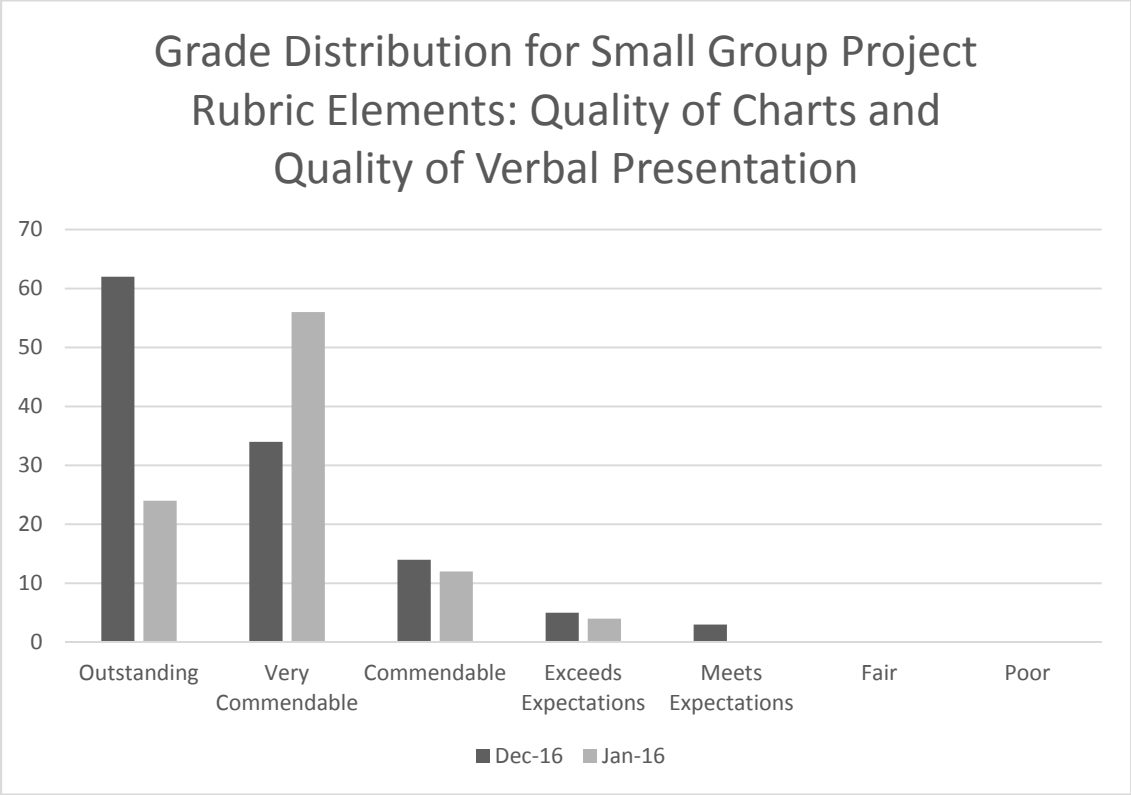

Figure 3 – Small Group Project Rubric Element Distributions for January and December Cybersecurity Classes

	December 2016				January 2016			
	Average	Standard Dev	Max	Min	Average	Standard Dev	Max	Min
Projects 1-4	95.4%	2.4%	98.2%	90.2%	89.6%	2.6%	93.6%	86.0%
Projects 5-9*	95.6%	4%	100%	88.4%	93.2%	1.6%	100%	88.4%
Cracking WEP Project	96.5%	2.9%	100%	91.2%	93.6%	1.2%	95.0%	92.0%

* A 9th project was assigned in the December 2016 class

Table 3 Comparison of Grades for Small Group Projects in Jan 2016 and Dec 2016 classes

The standard interpretation of effect size, as offered by Cohen (Cohen 1988) as it relates to its real impact on the team members is:

0.8 = large (8/10 of a standard deviation unit)

0.5 = moderate (1/2 of a standard deviation)

0.2 = small (1/5 of a standard deviation)

In this research, with the calculated Effect Size being equal to or above 0.78 for all projects, the effect size is large - the intervened group's mean score increased equal to or more than 8/10 of a standard unit. This indicates that the data show that the group collaboration had a major impact. The main difference between the grading rubric for small group projects in the January 2016 and December 2016 classes was that an element for "Teamwork" was added in the December class. However, it turned out to be difficult to get the project teams to record their suggestions in writing. Some teams did well, but other teams did not record any of their suggestions for improvement. The quality of the presentations was high, indicating that there had been a significant level of teamwork, but use of the group blog to capture the suggestions did not work well. This point will be revisited in the discussion of the Survey Results.

Survey of Student Perception of Enhanced Learning through Collaboration

A survey was sent to the 60 students enrolled in two December classes in which the two collaboration approaches were implemented: CSC 607 Security in Computing and Security and CSC 686 Computer Science Project 1. CSC 607 was an online class with an enrollment of 20 students. CSC 686 was an onsite class, with enrollments of 40 students. Students were invited to respond using a 5-point Likert Scale: Strongly Agree - 5, Agree – 4, Neutral - 3, Disagree - 2, Strongly Disagree – 1. 18 of the 60 students responded, for a response rate of 30.0%. The survey questions, along with the average responses to the first survey are shown below in Figure 4.

The average for twelve of the thirteen questions ranged from a low of 3.83 to a high of 4.28. One question, #7, stood out as having a significantly lower average than the other questions. One unhappy student responded to every question with disagree or neutral. There were no "strongly disagree" responses to 11 of the 13 questions, and only two "disagree responses on 12 or the 13 questions. Students were also invited to make any comments they wanted to make.

The results indicate that students felt the processes of mentored assignments and teamwork on projects improved the quality of their project report. 15 students responded "strongly agree" or "agree" on this question. None responded "disagree" or "strongly disagree".

Twelve students responded "strongly agree" or "agree" on the question #4 about whether the collaboration helped their learning. One student responded "disagree". There were no "strongly disagree" responses to this question. The assessment of improvement of critical thinking, # 12, is encouraging. Twelve students responded "strongly agree" or "agree." There was only one "disagree" and no "strongly disagree". Student were satisfied with the instruction they were given about how to collaborate, and about the instructor's contribution to the effectiveness of their groups' collaboration. No students responded "disagree" or "strongly disagree" to these questions.

1. **I was given adequate instruction about how to collaborate in a group**
   Weighted Average = 4.06
2. **My instructor contributed to the effectiveness of my groups collaboration**
   Weighted Average = 4.00
3. **The group collaboration improved the quality of my project?**
   Weighted Average = 3.94
4. **The group collaboration improved my learning**
   Weighted Average = 3.83
5. **I was effective in helping other members of my group learn**
   Weighted Average = 3.89
6. **The group collaboration improved the quality of my project report**
   Weighted Average = 4.06
7. **The use of Blackboard group tools improved my ability to interact constructively with my peers**
   Weighted Average = 3.17
8. **My peers provided constructive comments about my work/findings**
   Weighted Average = 3.89
9. **My group collaborated together effectively as a group**
   Weighted Average = 4.28
10. **All members contributed to the final results of my group**
    Weighted Average = 4.22
11. **My learning improved as a result of my interactions with other members of my group**
    Weighted Average = 3.94
12. **My critical thinking improved as a result of my group's collaboration**
    Weighted Average = 3.94
13. **Feedback from my peers during group collaboration stimulated me to explore new ideas on my own**
    Weighted Average = 3.89

Figure 4 – Survey Questions on Effectiveness of Student Collaboration

The question with the highest average response, #9, indicates that students were pleased with the effectiveness of their group work. 11 students answered "strongly agree" on this question. A common complaint from students about group work is that some members of the group don't contribute. However, the response to #10, indicates that, at least in these classes, students were satisfied with the contribution of the other members of their groups.

The overall response to the survey indicates that students agreed that the approach used to collaboration in these courses improved their learning experience. One of the student comments summarizes what most students thought. The student wrote, "Initially, I thought that the mentored assignments and group projects were an overwhelming amount of work. They did, in fact, add a lot more time and effort to assignments that would otherwise be individual but I think the collaboration added value to the course. The amount of work is what I should expect from a Master's course, so I am not going to complain about that. The collaboration definitely enhanced my learning experience."

The response to question #7 indicates that the group tools in our Learning Management System, Blackboard, did not satisfy the students, in enabling them to interact constructively with one another. One student commented, "Using tools that are relevant to industry standards, such as google hangouts, google docs, and Github, and even MS Office tools has helped work around geographic and time zone differences. Blackboard tools are fine for what they are meant to do but a poor substitute, poor performing, and a misfit for project collaboration tools." The number of seven students who "agreed" or "strongly agreed" on this question was identical to the number of students who "disagreed" or "strongly disagreed". This is an area in which the authors intend to do further work, possibly to try to develop some extensions to Blackboard to make it easier to connect with what this student labeled "industry standards" that would improve the experience for our students.

CONCLUSIONS

In order to assess the impact of collaboration, this research evaluates and compares projects undertaken using developed metrics/rubrics. The objectives were 1) to implement a process that ensures collaboration and to help student teams to improve the quality of the projects, 2) The process needs to be flexible so it can be used for both online and onsite courses, and 3) apply both qualitative and quantitative analysis to measure the final quality improvements – if any. The measurement rubrics were developed and the process was implemented. It was ensured that this process was flexible enough to be applied to both onsite (in-person) and online classes. For the qualitative analysis, a student satisfaction survey showed the results from the responses were positive with the introduction of collaboration to help improve the project quality. The survey also collected comments from the students. These were positive and some potential areas for improvement were suggested. For the quantitative analysis, each document was scored against a predeveloped rubric. For comparison and to quantify the improvement, several similar previous projects were analyzed. Average scores and standard deviations showed an overall quality score increase for these projects. In addition, this quantitative analysis showed that the probability of a document score from the experimental group to be higher than document score from the control group by a significant margin. Findings of this evaluation and analysis can lay the foundation for changes, recommendations, and deployment of collaboration practices in engineering curricula.

CONTINUING RESEARCH

This research was performed with a relatively small number of students, in two courses, and all in the engineering curriculums. This may be extended in scope and it is suggested that additional research be undertaken with students from different courses and different curricula. Additionally, technical programs and curricula need to be analyzed to understand the variations, if any, due to the topics covered. A research may be designed that incorporates possible quantitative and qualitative impact with available teaching and learning approaches. This can be taken further to

analyze the correlation between different teaching and learning paradigms (flipped classes, partially flipped classes, problem-based learning, accelerated courses, etc.) and the impact of collaboration on the project quality in these environments.

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Appendix A – Grading Rubric for Small Group Presentations

Small Group Presentation Grading Rubric	Outstanding	Very Commendable	Commendable	Exceeds Expectations	Meets Expectations	Fair	Poor
	96%-100%	90%-95.99%	85% to 89.99%	80% to 84.99%	75% to 79.99%	70-74.99%	less than 70%
Quality of Research	Eight or more relevant findings from research other than the textbook are discussed and compared	At least six relevant findings from research other than the textbook are discussed and compared	At least four relevant findings from research other than the textbook are discussed	At least two relevant finding from research other than the textbook is discussed	Nothing other than the textbook discussed	Some points from textbook discussed	No evidence of any research
Original Thinking	At least seven new ideas are introduced and their relevance is discussed in depth	At least five new ideas are discussed and their impact is explored.	At least five new ideas are discussed.	At least three new ideas are discussed.	At least one new idea is discussed.	One idea from textbook is discussed.	No evidence of original thinking.
Understanding of subject	Extensive analysis backed up by specific citations to research findings	Extensive analysis demonstrates understanding of subject.	Some analysis is provided, demonstrating understanding of subject.	Good understanding of the subject is evident in multiple sentences.	Some ability to apply understanding of the subject is evident.	Minimum understanding of the subject is evident.	No evidence of understanding of the subject.
Thoroughness of work	At least eight references. All facts backed up with specific citations throughout as well as at the end. All of the	At least six references, and they are cited throughout as well as at the end. Key facts are backed up with credible citations.	At least five references, and they are cited throughout as well as at the end.	At least four references provided at end. Some facts are backed up but there are some gaps.	At least two references provided at the end.	Only one reference (other than the Textbook). Major gaps in backup of facts with citations.	No references given. No facts backed up.

	backup is highly credible						
Organi-zation of material	Outstand-ing organi-zation between and within each section with multiple parts clearly identified and strong logical flow of ideas within each section and from one section to the next.	Very good organization between and within each section with multiple parts clearly identified and good logical flow of ideas within each section.	Multiple parts clearly identified with good logical flow of ideas from one section to the next.	Good logical flow of ideas.	Some logical progression of ideas.	Haphazard organization.	No organization evident.
Effect-iveness of presenta-tion	Exeption-ally persuasive. Almost everybody would agree with you.	Persuasive. Three fourths of the people would agree with your conclusions	Fairly persuasive. A majority of people will agree with your conclu-sions	Somewhat persuasive. About half the people would agree and half would disagree with your conclusions	Limited in persuasive-ness. Probably two-thirds of the people would disagree with your conclusions	Not persuasive. Less than a quarter of the people would agree with your conclusions	Almost nobody would agree with your conclusions
Team-work	All team members have provided extensive multiple suggestions in the Group Blog for improveme nt of the project	Each team member has provided multiple suggestions for improve-ment in the Group Blog	All team members have comment-ed. Some, have provided multiple suggestion s for improve-ment in the Group Blog	Each team member has provided at least one suggestion for improve-ment in the Group Blog	Some, but not all team members have provided at least one suggestion for improve-ment in the Group Blog	Only one team member has provided any suggestions for improve-ment in the Group Blog	No team member has provided any suggestions for improve-ment in the Group Blog

Length of presenta-tion	15 minutes plus or minus 30 sec	14 minutes + or – 30 sec or 16 min + or – 30 sec	13 minutes plus 30 sec or minus 30 sec or 17 min + or – 30 sec	12 min + or – 30 sec or 18 min + or – 30 sec	11 minutes plus or minus 30 sec or 19 min + or – 30 sec	10 minutes + or – 30 sec or 20 min + or – 30 sec	less than 9 and a half minutes or more than 20 and a half min
Quality of Charts	Exceptiona l charts with no spelling errors, no more than 7 words per bullet, plus at least four excellent pictures and/or graphics that are clearly relevant and amplify the presentatio n	Very good charts with no spelling errors, no more than 7 words per bullet, plus at least three pictures and/or graphics that are clearly relevant	Minimal misspellin g and grammar errors but meaning is clear. Concise words, and no point with more than 7 words on a chart. At least two relevant pictures or graphics.	Minimal misspelling and grammar errors but meaning is clear. Concise words, and no point with more than 7 words. At least one relevant illustrations.	Minimal misspelling and grammar errors but meaning is clear. Concise words only. At least one illustration.	Multiple misspelling and grammar errors but meaning is clear. Words only.	Many misspellings and grammar errors. Hard to understand. Words only.
Quality of verbal presenta-tion	Strong preparation . Points flow well for each presenter and across presenters. Excellent confidence. Is very persuasive	Strong preparation. Points flow well for each presenter and across presenters. Strong confidence.	Evidence of good preparatio n. Points flow well for each presenter but not across presenters. Good confidence .	Evidence of good preparation, but points do not flow well. Some confidence.	Some evidence of preparation. Some confidence.	Some evidence of preparation, but no confidence.	No evidence of preparation. Lack of confidence.

Appendix B – Grading Rubric for Writing Assignments

Small Group Presentation & Assignment Grading Rubric	Outstanding	Very Commendable	Commendable	Exceeds Expectations	Meets Expectations	Fair	Poor
	96%-100%	90%-95.99%	85% to 89.99%	80% to 84.99%	75% to 79.99%	70-74.99%	less than 70%
Quality of Research	Eight or more relevant findings from research other than the textbook are discussed and compared	At least six relevant findings from research other than the textbook are discussed and compared	At least four relevant findings from research other than the textbook are discussed	At least two relevant finding from research other than the textbook is discussed	nothing other than the textbook discussed	Some points from textbook discussed	No evidence of any research
Original Thinking	At least seven new ideas are introduced and their relevance is discussed in depth	At least five new ideas are discussed and their impact is explored.	At least five new ideas are discussed.	At least three new ideas are discussed.	At least one new idea is discussed.	One idea from textbook is discussed.	No evidence of original thinking.
Understanding of subject	Extensive analysis backed up by specific citations to research findings	Extensive analysis demonstrates understanding of subject.	Some analysis is provided, demonstrating understanding of subject.	Good understanding of the subject is evident in multiple sentences.	Some ability to apply understanding of the subject is evident.	Minimum understanding of the subject is evident.	No evidence of understanding of the subject.
Thoroughness of sources	At least eight references, and they are cited throughout as well as at the end.	At least six references, and they are cited throughout as well as at the end.	At least five references, and they are cited throughout as well as at the end.	At least four references provided at end.	At least two references provided at the end.	Only one reference (other than the Textbook)	No references given.

Organiza-tion of material	Outstanding organization between and within each section with multiple parts clearly identified and strong logical flow of ideas within each section and from one section to the next.	Very good organizati on between and within each section with multiple parts clearly identified and good logical flow of ideas within each section.	Multiple parts clearly identified with good logical flow of ideas from one section to the next.	Good logical flow of ideas.	Some logical progression of ideas.	Haphazard organizatio n.	No organizatio n evident.
Effective-ness of your conclu-sions	Exeption-ally persuasive. Almost everybody would agree with you.	Persuasive . Three fourths of the people would agree with your conclusion	Fairly persuasive. A majority of people will agree with your conclusions	Somewhat persuasive. About half the people would agree and half would disagree with your conclusions	Limited in persuasive-ness. Probably two-thirds of the people would disagree with your conclusions	Not persuasive. Less than a quarter of the people would agree with your conclusions	Almost nobody would agree with your conclusions
Thorough -ness of material	All facts backed up with specific citations. All of the backup is highly credible.	All facts backed. All of the backup is credible.	All facts backed. Most of the backup is credible.	All facts backed up but some gaps still exist	Most facts are backed up. No major gaps.	A few facts are backed up but there are major gaps	No facts are backed up.
Quality of Com-ments made to fellow students you are mentoring	At least 3 construc-tive com-ments pro-vided to each fellow student you are mentor-ing, with clear sug-gestions for improve-ment	At least 3 construc-tive com-ments pro-vided to each fellow stu-dent you are mentoring,	At least 2 construc-tive com-ments pro-vided to each fellow student you are mentor-ing, with clear sug-gestions for improve-ment	At least 2 construc-tive com-ments pro-vided to each fellow student you are mentor-ing	One constructive comment provided to each fellow student you are mentoring	One cursory comment provided to only one student you are mentoring	No constructive comments provided (if instructor was not emailed with your comments this is where you will fall in this category)