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Assessing the Impact of Game Based Pedagogy on the Development of Communication Skills for Engineers

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Assessing the Impact of Game-Based Pedagogy on the Development of Communication Skills for Engineers

Abstract

Communication is a vital component of education for any discipline, but it is essential to an engineering curriculum. Our study has investigated the impact that game-based learning, a form of active learning shown to increase a student's interest and motivation[1], has on the development of oral and written communication skills within a sophomore level chemical engineering class. Game-based learning incorporates game design elements, such as instantaneous feedback, an immersive nature, and scaffolding techniques, into non-game contexts in order to push students to the edge of their capabilities[2,3,4].

In the spring semester of 2014, two sections of this chemical engineering course, entitled Introduction to Chemical Product Design, were taught. While both class sections used traditional lecturing and several active learning strategies, including think-pair share, group discussion, and case studies, only the experimental (game-based) class section utilized game-based pedagogy. However, the same communication curriculum, which included translating scientific information for public audiences and strategies for a good oral presentation, was delivered to both sections. Final written reports and video infomercials, produced as part of a semester long design project, were evaluated by two analysts. The results from each section were then compared to determine the impact of game-based learning on students' achievement in communication skills, both written and oral. The written report was evaluated using the *Written Communication VALUE* rubric, which was developed by faculty experts sponsored by the Association of American Colleges and Universities. This *VALUE* rubric evaluates a written report based upon five categories – context of and purpose for writing, content development, genre and disciplinary conventions, sources and evidence, and the control of syntax and mechanics[5]. The video infomercial was evaluated using the Elevator Pitch Evaluation Rubric, created by faculty at Rowan University for a sophomore-level design course. This rubric considers content, organization, style, delivery, and the overall presentation[6]. Both the written and oral assignments were double coded to ensure the quality of the assessment, and an inter-rater reliability measure was calculated for the two analysts.

In the comparison of written reports from the games versus non-games sections of the course, the mean overall score was higher for the games-based teams (n=13) compared to the non-games-based teams (n=14), although not significantly. This was likely influenced by the small sample size. This trend also existed with the mean scores for each dimension of the rubric. The same was generally true for the oral (infomercial) results. The games-based teams scored higher than the non-games-based teams on four of the five rubric dimensions, although not significantly. The course instructors were also interviewed to determine their impressions of the differences between the students in the games vs. non-games sections, based upon classroom activities and homework submissions.

Finally, this study also examined whether students' perceptions of their development of communication skills within the particular section of the course correlated with their performance on the oral and written assignments. To assess this, a selection of questions from

the National Survey of Student Engagement pertaining to perceptions of communications skill development was compared to the scores achieved on the written and oral communication assignments[7]. Based on our small sample of data, we did not find a relationship between student perception and the team's performance.

1. Introduction and Literature Review

Communication is an important component of education for any discipline, but it is vital to engineering. In the past, engineers' lack of communication amongst themselves, as well as with colleagues from different fields, has resulted in devastating outcomes, such as the crash of the Mars Climate Orbiter (MCO) in 1999. A lack of communication between the engineers working for Lockheed Martin Astronautics (LMA) and those in NASA's Jet Propulsion Laboratory resulted in English units, rather than NASA's standard metric units, being utilized in software that was used to calculate trajectory models. Furthermore, the absence of communication between NASA engineers working for different project elements of the MCO resulted in the problem going unreported and unrepaired. While the operations navigation team noted that their trajectory was different than that originally calculated using the software from LMA, they failed to formally report their concerns to the spacecraft operations team or project management. It was noted by the MCO Mishap Investigation Board that this team seemed to be isolated from both the other project divisions and its own line organization, due to lack of communication. For example, when discrepancies in the data tracking the movement in the MCO was detected, the operations navigation team relied on subpar email communications to attempt to solve the problem. Instead, the team should have completed formal and descriptive methods of communications, such as the Incident, Surprise, Anomaly (ISA) reporting procedure. These communication issues caused the MCO to travel too closely to Mars' atmosphere, where all communication was lost with the $125 million spacecraft[8].

Similar previous failures and a general dissatisfaction from industry employers in engineers' nontechnical professional abilities, such as communication and teamwork skills, led ABET to create an Accreditation Process Review Committee (APRC) in 1992. Drawing recommendations from workshops and public comments to create new criteria, ABET approved the *Engineering Criteria 2000* (EC2000) in 1996. Two of the learning outcomes listed in EC2000 are the ability to function on multi-disciplinary teams and to communicate effectively[9]. ABET has retained these two learning outcomes to this day[10], which demonstrates the continued importance that ABET places on these skills. The new criteria in EC2000 resulted in faculty altering their teaching methods by increasing their use of active learning approaches, such as design projects, case studies, and group work. The change in criteria and teaching methods resulted in both students and employers indicating an increase in communications and group skills when 2004 graduates were compared with 1994 graduates[9].

However, despite these efforts and noted progress, many employers still do not regard graduating students as being prepared for the workforce, particularly in "soft" or professional skills, such as communication, creativity, and collaboration. In a survey conducted by the Workforce Solution Group, more than 60% of employers noted that many students applying for a position lack "communication and interpersonal skills"[11]. In a pre-workshop survey from an American

Society for Engineering Education and National Science Foundation workshop, thirty-three participants from both industry and academia were asked to determine what abilities would be most important within the next decade for engineers and whether current students exhibited those abilities. Current students were perceived to underperform and were considered unprepared for the workforce in many of the agreed upon requirements for future engineers, such as communication and decision-making skills[12]. Therefore, additional training in these areas will need to be provided to students to address these concerns and handle the changing professional landscape they will enter after graduation. As engineering issues become increasingly complex, collaborative teams, populated by multidisciplinary teams of experts, will be required. These teams must excel at communication with both technical and non-technical audiences, so that team members, educated in different fields, can have a firm understanding of all of the material being presented[13]. Open and clear communication are also beneficial in cases such as that of the MCO incident. Teaching methods for communication must be improved upon in order to better prepare engineering students for the changing requirements of the workforce[9].

Our study has investigated the impact that game-based learning, a form of active learning shown to increase a student's interest and motivation[1], has on the development of oral and written communication skills within a sophomore level chemical engineering class. Game-based learning is an appealing pedagogy to students due to the pervasive nature of games in our society, where people can "play" video games or collect points for a free coffee[2]. However, it also appeals to educators because game-based learning incorporates game design elements, such as instantaneous feedback, an immersive nature, and scaffolding techniques, into non-game contexts in order to push students to the edge of their capabilities[2,3,4]. While many traditional teaching methods entail a punitive aspect, often without providing the student with any feedback in the form of corrections, game-based learning provides instantaneous feedback so that students can persist until they achieve the correct answer, learning and improving from each failure[2]. Since games allow students to repeatedly try without repercussions, they encourage reflection on what mistakes were made and how to avoid these issues in the next attempt at the problem[14]. This reflection allows the students to make their own connections between previous and current classroom content, and how to best apply it. When a player does finally overcome a particularly difficult challenge they can experience "fiero," which is documented by neuroscientists as one of the most powerful neurochemical highs that a person can experience[2,3]. The drive to overcome struggle and experience this emotional rush keeps players fully engaged and contributes to the immersive nature of games. Another educational property of games is scaffolding, in which ample information and support is initially provided to teach the basics of a subject, and then, as the student becomes increasingly adept, the challenges increase and the scaffold is slowly withdrawn[4]. These game design elements were incorporated into one class section of the Introduction to Chemical Product Design course in varying formats, including classroom activities and an online gamified homework portal known as 3D Game Lab[15].

In this study, we had the following two research questions:

1. *Does game-based learning, as utilized within a sophomore level chemical engineering course on chemical product design, have an impact on team-based oral and written communication skills?*

2. *Is there a relationship between perceptions of communications skills development in each section of the course (i.e., games versus non-games) and performance on the written and oral projects?*

2. Methods

2.1 Study Design

This study was conducted with two sections (games vs. non-games) of the Introduction to Chemical Product Design course, which is a required sophomore level chemical engineering course designed to promote innovation and entrepreneurship. Fifty-seven students were randomly enrolled in each of the non-games (control) and games-based (experimental) sections. Both class sections were taught using a combination of traditional lecturing and active learning methods, including clickers, think-pair-share, and group discussions. However, the experimental class section also incorporated game-based learning techniques, including classroom-based games, such as "categories," and "traffic jam", and a gamified homework portal. In "categories", students are all given a different card with a word or phrase on it and then they need to utilize their non-verbal communication skills to portray their word to others in the class. The goal at the end of a round is for students to group together in categories based upon the words that they were given and the only rule for the game is that students are not allowed to talk. This game is a great forum for opening up discussion about how difficult non-verbal communication can be and how methods such as pictures can be very helpful in portraying concepts that otherwise might be impossible to communicate without words. The game "traffic jam" focused on the development of decision making skills. Two groups of students were lined up in a row facing one another with one available space in between the groups. They were then instructed that they needed to get all of the members of their team to switch places with the team in front of them but with the constraint that they could only move forward on an empty space or move around a single person to an empty space. This game served as a great foundation for discussing how many problems we face that seem relatively simple from the onset but once you start working on the problem you realize that there are many more difficulties involved in reaching a solution and that the decisions that need to be made are not always as simple as anticipated. While the control section had traditional weekly homework assignments, the experimental section received these same homework questions in a gamified online environment. The only requirement for the game-based homework assignments was that they be completed by the end of the semester. Scaffolding and instantaneous feedback were built into the gamified homework portal. Students were first presented with tasks that didn't require experience in a particular course outcome area and as they succeeded with these initial assignments the difficulty level of the problems presented gradually increased. In addition, submitted answers were either accepted with comments or returned with suggestions for improvement until an acceptable answer had been submitted. The classroom activities centered on the instruction of oral communication, while the gamified homework assignments focused on improving the students' written communication skills.

The curriculum in both class sections dedicated two weeks to the development of both written and oral communication skills. The communication topics included: translating scientific information for public audiences, identifying the target audience and methods for tailoring a

presentation to that particular audience, communication to diverse audiences, strategies for good oral presentations, written reports vs. memos, and the importance of remaining professional while conducting e-mail communication with colleagues. The course was co-instructed by two chemical engineering faculty members.

In order to test the impact that the variation in teaching methods had on students' communication skills, they were asked to complete semester-long projects in groups of three or four. These projects, designed to assess their communication skills, included a written market analysis and an infomercial for a sunscreen product. These projects were then evaluated using the *Written Communication VALUE* rubric for the market analysis and the Elevator Pitch Evaluation Rubric for the infomercials. The assessment analyst also conducted a joint interview with the instructors after the course to further assess differences in the games versus non-games sections. In addition, the students completed a perception survey, based on questions from the National Survey of Student Engagement (NSSE), to assess their communication skills development during the course. All necessary human subjects' clearance was obtained before beginning this study.

2.2 Grading Rubrics and Perception Survey

The written report, focused on the market analysis of sunscreen, was evaluated using the *Written Communication VALUE* rubric, which was developed by faculty experts in an initiative sponsored by the Association of American Colleges and Universities. This *VALUE* rubric evaluates a written report based upon five categories - context of and purpose for writing, content development, genre and disciplinary conventions, sources and evidence, and the control of syntax and mechanics. Each of these categories uses a scale of 1 to 4, with 4 being the most desirable[5]. The oral project (i.e., video infomercial) was evaluated using the Elevator Pitch Evaluation Rubric, created by faculty at Rowan University for a sophomore-level design course. This rubric considers content, organization, style, delivery, and the overall presentation. The rubric uses a scale of *Unacceptable, Poor, Average, Good, and Excellent*[6]. For grading purposes, we translated this into a number scale ranging from 6 to 10, with 10 being the most desirable. To determine the written score for each team, the scores assigned to each dimension of the Written *VALUE* rubric were averaged. The oral score for each team was similarly determined by averaging the scores from the dimensions of the elevator pitch rubric. To determine the impact of the game-based learning on the students' communication skills, the written and oral scores for the sections were compared using both a t-test and the Mann Whitney test given the small sample size.

In the second-to-last week of the semester, students completed a perception survey that was based on questions from the National Survey of Student Engagement (NSSE)[7]. The survey asked the student to assess the extent to which the course contributed to his/her knowledge, skills, and development in "writing clearly and effectively" and "speaking clearly and effectively." The survey utilized a scale that ranged from 1 to 4, which corresponded to *Very Little, Some, Quite a Bit*, and *Very Much*. Since the perception survey was distributed on an individual-student basis, we averaged the ratings for each member of the team to get a team-based perception of its written and oral development. For teams of four, a team-based score was only calculated for those teams in which three or more members responded to the survey to

ensure representativeness. For teams of three, at least two members had to have responded.

For each of the games and non-games sections, we correlated the team's performance score (obtained from the rubric) with the team's perception of the course's contribution to its communications skills. This indicated the degree of the relationship between the team's perception of the value or academic gains associated with the course in this area and the team's actual communications achievement. We surmised that students in the games-based section would have perceived more opportunities to develop their communication skills due to the number of games that required group discussion and the nature of the writing-based homework assignments requiring multiple submissions until all standards were met. By examining the games versus non-games sections separately, we could identify any differences between the two groups. Given our small sample sizes, we examined both the Pearson and Spearman correlation coefficients, with the Spearman being a nonparametric coefficient.

2.3 Reliability Analysis

Each written report and infomercial was independently scored by two coders. One coder was a faculty member and the instructor of the course. The other was the assessment analyst for the project. When the coders disagreed on a score for a certain dimension, they discussed until agreement was reached, which sometimes involved averaging their scores to obtain a final score. Nonetheless, for their use of the Written *VALUE* rubric, their first-time reliability based on the overall intraclass correlation coefficient (*ICC*) was 0.73, which represents good reliability[16,17]. The *ICC* is often used to measure agreement between raters' numerical scores[17]. For this overall *ICC* value, we included all dimensions in the calculation. We also calculated an *ICC* for each individual dimension of the *VALUE* rubric. These values were in the range of 0.56 to 0.73, suggesting fair to good reliability for each individual dimension[16,17]. With the use of the elevator pitch rubric, our overall *ICC* (i.e., not broken down by dimension) was 0.59, which represents fair to good reliability. For the individual dimensions, we achieved *ICCs* that suggested fair to good reliability for all but one of the individual dimensions. Since this was our first use of the rubric, we have developed a training and review plan for our next round of coding to increase our first-time reliability. To explore the reliability of the elevator pitch rubric further, we contacted its developer[19]. He provided us with data that his team had collected using the rubric. This data showed *ICC* values between 0.64 and 0.75 for the various dimensions of the rubric, suggesting good reliability. All *ICC* values were based on the "average measure" in *SPSS*[18].

3. Results and Discussion

3.1 Statistical Comparison of Written and Oral Projects

Based on our small sample of n=13 games-based and n=14 non-games-based teams, we noticed a trend towards higher average scores for the games-based teams. The scores for each of the five dimensions of the *VALUE* rubric and the average score across the dimensions were higher for the games-based teams, as shown in Table 1. None of the differences were statistically significant; however, the samples were small. There was general agreement between the p-values of the t and Mann Whitney tests, and both tests suggested non-significance of the differences.

Table 1: Results from the Written Communications VALUE Rubric

Dimension	Definition	Game AVG	Non-Game AVG	p-value (t)	p-value (Mann Whitney)
Content	Introduction gained attention and developed interest by appealing to the audience. Presentation has a clear ending, and ended with a memorable closing statement.	8.50	8.67	0.637	0.722
Organization	Presentation was easy to follow and contained a clear intro, body, and conclusion. Transitions were used effectively throughout the speech.	8.40	8.25	0.636	0.674
Style	Language choices create a persuasive tone and interest, and were clear and accurate.	8.50	8.42	0.712	0.771
Delivery	Maintained eye contact, used voice effect and physical action. Adhered to the time limit of 2 min, and utilized an extemporaneous style.	8.40	8.00	0.342	0.228
Overall	Presentation developed a strong persuasive appeal and approach, and was adapted to the target audience	8.40	8.25	0.636	0.674
Average of Dimensions	Average score of the above five dimensions.	8.440	8.317	0.642	0.674
	Sample Size (n)	10	12		

With the infomercial results, we noticed a similar trend with the small sample of n=10 games and n=12 non-games-based teams, with four of the five dimensions as well as the average of the dimensions higher for the games-based teams. There was also corroboration between the p-values of the t and Mann Whitney tests, and the non-significance of the results was supported by both tests.

Table 2: Results from the Elevator Pitch Evaluation Sheet (Rowan University)

Dimension	Definition	Game AVG	Non-Game AVG	p-value (t)	p-value (Mann Whitney)
Context of and Purpose for Writing	Considered the audience, purpose, and circumstances surrounding the writing topic.	2.88	2.75	0.461	0.488
Content Development	Used compelling content relevant to the subject.	2.58	2.07	0.068	0.128
Genre and Disciplinary Conventions	Followed both formal and informal rules inherent in the appropriate discipline.	2.27	2.07	0.470	0.458
Sources and Evidence	Used credible sources with evidence appropriate to the topic.	2.19	2.07	0.663	0.720
Control of Syntax and Mechanics	Used language that clearly communicates all information to the audience with few grammatical errors.	1.62	1.46	0.547	0.350
Overall Score	Calculated by averaging the scores of all dimensions.	2.308	2.086	0.203	0.550
	Sample Size (n)	13	14		

3.2 *Interview*

In the joint interview with the instructors, both oral and written communications skills were discussed. Relative to oral communication skills and behaviors, the instructors noted that students in the games-based class were more talkative and communicative in terms of providing responses to the instructors' questions. Based on the instructors' assessment, the games-based students also obtained a higher level of achievement with the impromptu presentations they were required to give in class. These students were observed to be more comfortable with being in front of the class for these presentations. The games-section students seemed to begin discussions right away when there was group work to do.

In terms of written communications skills, there was a noticeable progression in the students' writing skills in the games-based section, as determined using the 3D Game Lab portal, which consisted mostly of writing assignments. As an example, students had to transform a scientific abstract into a written piece that could be read and understood by someone who did not necessarily have an engineering background. One of the instructors assessed the Game Lab submissions on a daily basis and typically required students to re-submit them for improvements. As the semester progressed, the instructor noticed a decrease in the number of times students had to re-submit their written responses for needed improvements. At the beginning of the semester, students typically had to re-submit an average of 3 times (estimated), with some as many as 8 or 9 times. Towards the end of the semester, the instructor noted many fewer re-submissions required (estimated 1 or 2 on average), despite an increase in the difficulty of the assignments over time. As a side note, the other instructor has noticed that the students' writing abilities in the follow up course (CHE-0314 Taking Chemical Products to Market) are quite good.

3.3 Correlation of Student Perceptions with Performance

The student responses in the perception survey regarding the development of their communications skills in the course were correlated with their scores on the written report and infomercial. There were two records for each team that contributed to the correlation calculation – one record associated with just the writing score and the other associated with just the oral/infomercial score. Thus, we investigated the nature of the relationship for communications skills *as a whole*. This was done largely in part to increase our sample size for the correlation calculation. However, our sample sizes were still small, with n=17 games-based records and n=21 non-games records. For the games section, as shown in Figure 1, we found a weak negative correlation between a team's perception of the course's contribution to these skills and its actual achievement, based on both the Pearson and Spearman coefficients. Pearson's r was -0.11, and Spearman's rho was -0.05. However, neither coefficient was statistically different from zero (p=0.86 based on Spearman's), suggesting no linear relationship from a statistical standpoint.

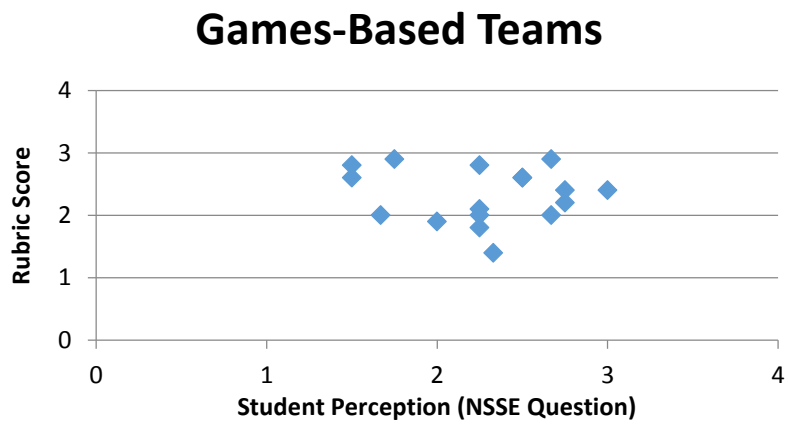

Figure 2: Relationship between game-based students' rubric scores (both written and oral) and perceptions of development in the course.

When examining the non-games-based teams, there was a weak positive correlation as shown in Figure 2. Pearson's r and Spearman's rho were each 0.04. Neither of these coefficients was statistically different from

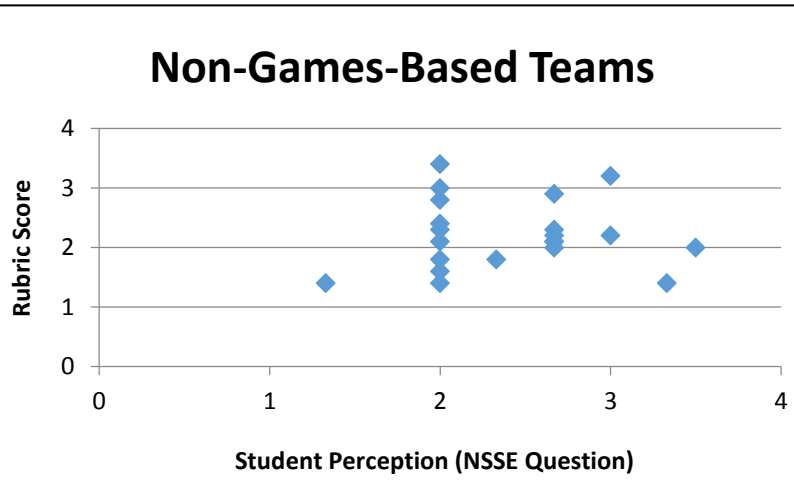

Figure 1: Relationship between non-game-based students' rubric scores(both written and oral) and perceptions of development in the course.

zero either (p=0.88 based on Spearman's). Thus, at this point, we do *not* have evidence of a relationship between a team's perception of the course's value or contribution and the team's achievement in communications skills for either the games or non-games-based teams. It's possible that students don't always realize the benefits of participating in activities such as games until much later in their academic development. On the surface a game may seem like play, but like the great educator Comenius said, "Much can be learned in play that will afterwards be of use when the circumstances demand it." Given the small sample sizes associated with our correlation results, they must be considered as preliminary trends at this point in time.

4. Conclusions

One method of educating engineers in skills that are beneficial and even necessary in the work force, such as oral and written communication, is games-based learning. This pedagogy incorporates game design elements, such as instantaneous feedback and scaffolding, into instructional programs. This pedagogy was incorporated into one class section of a sophomore-level chemical product design course to determine its impact on students' communication skills.

Our preliminary results show a trend for higher written and infomercial/oral scores for the games-based teams, indicating that the games-based learning methods may have a positive impact on the students' communications skills. With the collection of additional data during the second half of our study, we may be able to show statistical significance of the results as well. The reflections of the course instructors established that the games-based class demonstrated increased engagement with and performance on the classroom active learning exercises, including the required impromptu presentations. Also, based on the instructor's evaluation, the games-based students showed a significant improvement over the duration of the semester in their written homework submissions to the 3D Game Lab portal. At this point in time, we are unable to determine a statistically significant relationship between the students' rubric scores and their perceptions of the course's contribution to their communications skills development, likely due in part to the small sample sizes. It is also possible that the students did not fully realize the depth or importance of the communications skills they were taught using the games-based techniques, since the time span of the communications instruction was only two weeks.

One limitation of our study is the small sample size within each class section. Due to the number of students within the class, it was desirable to have the students work in groups of three or four, which did decrease the size of the sample that we could test. This course will be taught again in the spring of 2015, and the addition of those students to the current sample will increase the sample size, allowing us to conduct further statistical analysis on the data. The increased sample size may allow us to infer statistically significant conclusions. These results, demonstrating positive gains in learning outcomes without statistical significance are comparable to other studies conducted on the improvement of learning outcomes with the utilization of game-based pedagogy. In a recent literature review, the use of games as an educational tool in undergraduate engineering classrooms was examined. A total of 128 papers were discussed, 33 of which focused on the improvement of specific learning outcomes, some of which were communication and teamwork skills. Of these 33 papers only 24 conducted statistical analysis, with 12 papers conducting inferential statistical analysis and 12 conducting only descriptive analysis. Only 6 of the papers were able to claim statistical significance. However, as can be seen with this study,

positive results still occurred. Of the 24 papers that conducted some form of statistical analysis, 23 of them reported positive gains in the student learning outcomes for the game-based classroom, and 19 of the papers reported increased positive attitudes, such as confidence and engagement.[20] Our paper would currently be categorized among those that conducted inferential statistical analysis but were unable to draw statistically significant conclusions. Therefore, we will continue to expand our sample size so that we can possibly transition from reporting general trends of positive gains with our learning outcomes to statistically significant results.

Another potential limitation is the amount of time that was devoted specifically to communications skills instruction in the course, given the numerous other curricular topics that had to be covered. Unfortunately, communications skills could only be discussed for two weeks due to other necessary topics. In the future, we plan to consider additional forms of qualitative analysis, such as student focus groups, to help support the results we have observed based on the quantitative studies we have performed.

Based on our study, game-based learning has shown promising preliminary results for its ability to improve engineering students' written and oral communications skills and should therefore be investigated further for these outcomes.

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