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Investigating Potential Gender Differences in First-Year Engineering Students' Academic Motivation and Homework Submission Behavior

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Abstract

Previous studies have shown that there exists a difference in undergraduate students' academic motivation based on gender. Specifically, females have been shown to be more extrinsically motivated than their male peers in a university setting [1]. However, little research has been done to examine the effects of gender relevant to academic motivation in gamified systems. The study of gamification systems is important due to the increase in their use within educational activities. This study leverages the Jones MUSIC Model of Academic Motivation and gamification profiles to answer the research questions: (1) Are there differences in academic motivation towards the online gamified homework portal based on gender? and (2) What effects does gender have on submission behavior in an online gamified homework portal? Academic motivation was determined through student responses to the MUSIC Model survey. Behavior was measured through gamification profiles that measured submission behavior over the course of the semester. The data was analyzed using descriptive statistics to determine if any meaningful differences existed. Overall, it was shown that females have consistently higher overall academic motivation scores than males. It was also shown that males have a wider distribution of gamification profiles, ranging from disheartened behavior to overachieving behavior. Females, on the other hand, were more likely to have a consistent homework submission behavior.

Introduction

Many advances in STEM education, specifically those focused on technological methods and inclusive practices, have served to try to address the gender gap that still remains within engineering [2]. For instance, Mara Wasburns, "Is Your Classroom Woman-Friendly? Ten Strategies for Reaching This Goal." resource focused on the social basis for inclusivity. In this article, Wasburns suggests providing a gender-neutral classroom by avoiding using sports examples or providing assessments earlier and more frequently [3]. Other strategies for gender-focused inclusion can revolve around assigning personal reflections for students to help underrepresented engineering students feel a stronger sense of belonging [4]. While these strategies may prove useful for building inclusive class-based environments, these strategies may fall flat when students are utilizing technology as part of their instructional practice.

Technology is a critical part of instructional design; however, the types and implementation of technology can affect the success and motivation of students. For example, women are heavily influenced by the perceived difficulty of a new technology while men are most influenced by their attitude towards the adoption of a new technology [5]. One form of technology that has been gaining attention in educational settings is the incorporation of game-based elements, referred to as gamification [6]. Studies have produced unclear and sometimes contradicting results on whether the use of game elements has the potential to increase academic performance in such a way that it can be considered an inclusive practice [7], [8]. Furthermore, male and female students are known to perceive gamification differently and therefore benefit in different ways [8]. Researchers have begun to emphasize the importance of studying user experiences and gender imbalances to inform the future development of technologies and gamification strategies [9], [10]. For these reasons, educators must consider elements of inclusivity when developing or implementing gamified interventions.

The adoption of game elements for educational contexts appears to create an equal opportunity environment for students of any gender to engage with a more motivating structure of education

[11], [12]. However, it has been shown that gender is an influential factor of motivation [1], [13]. Without accounting for the differences in motivation for each gender, these gamified interventions may have yet to reach their full potential. This study aims to identify possible gender effects in academic motivation and behavior in a computer-based gamification platform that is implemented in a first-year engineering design course.

Background

This section will provide an overview of prior work related to gender differences relevant to motivation and then gender differences that have been observed in gamification settings to better situate the proposed study.

Motivation and Gender

There is no one prevailing theory of student's motivation yet the topic remains an attractive, if not necessary, area of research for engineering educators. Two popular theories of motivation that have been employed for studying gender include self-determination theory [14], [15] and expectancy value theory [16]. Theories of motivation have been useful tools for gaining insights surrounding the pursuit of STEM degrees and attrition issues [17] and to help explain differences in self-regulated learning [18]. As early as elementary school it has been found that males and females value education differently and as a result, are motivated by different tasks and outcomes [19], [20]

These gender differences in motivation are thought to be at least partially rooted in sociocultural influences such as gender stereotypes, parental influence, and implicit bias [20]. A study completed by Orr et al. [17] showed that, within higher education, engineering students as a whole are considered to be motivated differently from students in other programs. In their study, both male and female students in engineering were less motivated by tasks that involved working alongside others rather than individual tasks. In addition, female engineering students were less likely than male students to be motivated by becoming well known but more motivated by having increased job opportunities [17]. Females and males are not only motivated by different outcomes, the two groups differ in how they maintain motivation throughout the completion of a task. Another study done by Rodriguez and Esparragoza [21] found that female engineering students were more likely to be consistent in their motivation when measured using the Intrinsic Motivation Inventory before and after a difficult task whereas males were more likely to change in their self-reported motivation based on the perceived difficulty of the task.

Gamification and Gender

Gamification refers to the integration of game elements and game mechanics into non-game contexts with the goal of modifying the behavior of the user [11], [22]. Education research has developed a niche around the inclusion of popular game elements such as points, badges, and leaderboards. These three have been called the 'PBL' method of gamifying classrooms and can be introduced to improve motivation, engagement, and knowledge retention [22]–[25]. While many studies find that gamification ultimately has positive results on motivation and performance [22], [25], some studies have found that game elements can harm the intrinsic motivation of students and subsequently decrease student performance as well [15], [26].

Although these studies show insight into how gamification settings may impact student motivation and behavior in general, little work has been completed on the gender differences that occur within these contexts. An example of a study that sought to determine if motivational differences existed between male and female students when using a PBL-inspired online gamification platform is the study by Pedro et al. [7]. Their results showed that the gamification platform increased the motivation of male students but achieved little to no effect on the female students. Additional evidence for how male and female students differ when exposed to gamification comes from Koivisto and Hamari's [10] study on a gamification phone app. They found that females using the app were engaging more with the social aspects of the app, such as leaderboards and targeted competition than the male users. Male users were also less likely to encounter issues with the technology compared to the female users.

The ability to personalize learning using gamification is appealing for its potential application as a means to improve inclusive teaching practices, however evidence has shown that these benefits may not be equally distributed amongst male and female students [7], [26]. From these limited studies, it is clear that males and females differ in their experiences using gamified platforms. Further exploration of these differences in motivation and behavior as a result of gender effects and the intentional design of gamified platforms to meet these needs will be valuable to ensure that gamification can be an inclusive educational tool.

Research Questions

This study seeks to answer the following two research questions:

1. Are there differences in academic motivation towards the online gamified homework portal based on gender?
2. What effects does gender have on submission behavior in an online gamified homework portal?

Methods

This study was completed using data from the spring 2019 semester of a first-year engineering design course. The first-year engineering design course covers topics including commonly used engineering tools, statistics, economics, engineering ethics, and product development. The course involves in-person interactive class sessions but has additional coursework that is completed outside of class time such as online textbook questions, course project deliverables, and homework assignments. Homework assignments for the course were completed using an online gamified platform called Rezzly [27]. The sample of students in this study consisted of 169 males and 49 females spread across multiple sections. Male and female students are the only two genders included in this study due to the sample sizes obtained.

Rezzly

The Rezzly system structures homework to enable students to progressively build up their expertise in the course by gaining experience points (XP) from homework questions or "quest" completion [27]. Students have the freedom to select which quests to complete and during which time frame. Quests were divided up into categories based on core content areas covered within the first-year engineering design course for a total of 11 different categories. Rezzly's system also provides students with a variety of game-based elements including badges related to quest completion and a leaderboard. More details on the Rezzly platform and its implementation can

be found in existing publications [28, 29]. All students create an anonymous gamertag when first entering into the platform to ensure that their homework performance is not publicly available to other students within the course from the leaderboard.

As part of their homework requirements, students were required to attain 1,250 XP by the end of the semester, which was equivalent to approximately 35 to 40 homework questions (quests) depending on the gamification elements the students pursued. Students using this platform were also given benchmarks in which a certain number of experience points (XP) were required to assist with making the end of semester completion requirement. Personalized feedback was given to students by a team of upper level engineering student graders within 48 hours of the quest submission. In addition, students were given an infinite number of attempts for any given quest. The Rezzly platform itself is no longer in business due to the effects of the COVID-19 pandemic, however, the data provided by the Rezzly system has been archived including the full details of each quest submitted. The archived data was collected directly from reports provided by the online platform, which includes the de-identified student information as well as the weekly XP for each student. The weekly XP is further divided into the XP earned per content category as well as information regarding the badges and achievements earned.

The two primary tools for characterizing motivation and behavior in this study are the Jones MUSIC Model of Academic Motivation [30] and the identification of gamification profiles based on work done by Barata et al. [31].

Jones MUSIC Model of Academic Motivation

The Jones MUSIC Model of Academic Motivation utilizes a 26-item questionnaire to quantify the academic motivation of students [30]. The MUSIC model was created specifically to capture the motivational components of empowerment, usefulness, success, interest, and caring within higher education settings. Instructions for calculating the motivational scores were followed from the user guide provided by Jones [32]. This framework was chosen instead of other motivational frameworks due to its focus on academic motivation and its alignment with game-based learning elements in the Rezzly platform, such as the ability of students to have choice over quest completion.

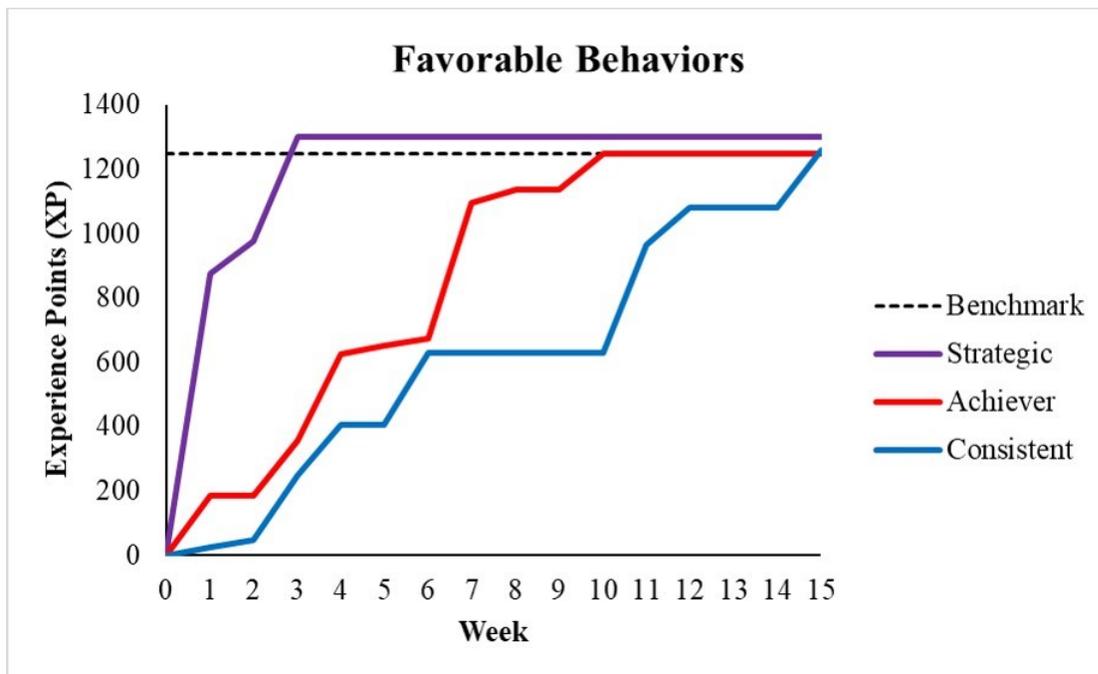
The MUSIC Model survey was given to students at the completion of the semester. The motivational data was analyzed by gender under the assumption that the behavior on the platform influenced the answers to the survey. Descriptive statistics such as the averages and standard deviations of the data were used to compare the two genders studied here, male and female. A one-way Bayesian ANOVA was used to compare the means between each gender for each construct of the MUSIC model. The Cohen's D effect size was also calculated to further determine the statistical significance of any gender effects found.

Gamification Behavior

The behavior of students using the Rezzly platform was a key area of interest. Student behavior is quantified through the generation of student gamification profiles. The generation of the gamification profiles was done referencing Barata et. al's [30] framework for analyzing student behavior in gamified settings. This framework categorizes students into five primary behaviors: disheartened, halfhearted, late awakener, consistent, and achiever. The disheartened and halfhearted student behaviors are characterized primarily by the failure to meet a final

benchmark XP, with halfhearted students reaching the halfway point and disheartened students remaining below the halfway benchmark through the entirety of the course. Students that fall into the late awakener category earn the majority of their XP in the second half of the semester. Consistent students are characterized by a regular pattern of earning XP. Key features of consistent student behavior in this course include reaching the four XP benchmarks and successfully reaching the final benchmark XP. Students that exceed the benchmark XP throughout the course and potentially end above the final benchmark XP are categorized as achievers. A new gamification profile, representing strategic students, was created as an extension to this initial framework by Kulhanek et al. [28] and is used to describe student behavior that could not be accurately characterized as consistent or achiever.

Gamification profiles were generated using logic statements in Microsoft Excel. These six profiles were further characterized into one of two groups: favorable and unfavorable behavior. The disheartened, halfhearted, and late awakener profiles were designated as unfavorable behaviors and the remaining consistent, achiever, and strategic profiles were designated as favorable behaviors. Exemplary graphs for favorable and unfavorable behaviors are provided for reference in Figure 1. IBM SPSS 26 was used to perform a Z-Test between these two categories of behavior for both genders to identify if these two groups were statistically different in a significant way.



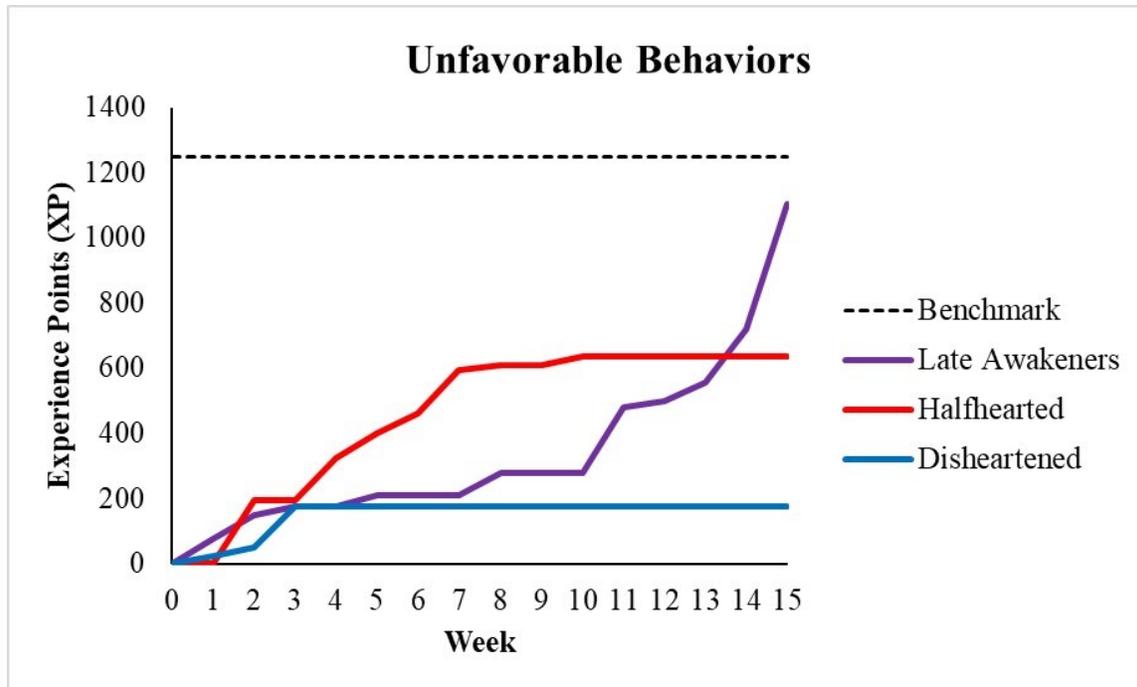


Figure 1: A visualization of favorable (top) and unfavorable (bottom) self-pacing behaviors on the Rezzly online gamified homework platform.

Results and Discussion

Differences associated with gender were found in both the academic motivation and submission behavior in this study. The results of the Jones MUSIC Model of Academic Motivation Questionnaire are presented along with the number of students that fall into each gamification profile and how these results differ for male and female engineering students. Notable results will be highlighted and discussed in the context of current literature.

Research Question 1: Are there differences in academic motivation towards the online gamified homework portal based on gender?

By utilizing the MUSIC Model survey, we found that female engineering students had higher overall academic motivation scores than male students as shown in Table 1. Four motivational constructs- empowerment, usefulness, success, and caring- were found to have statistically significant gender differences with medium effect sizes [33]. The motivational construct interest does not appear to be more or less important to either gender studied here. Another study that used the Jones MUSIC Model of Academic Motivation at the completion of an online course taken by undergraduates found similar results, which implied that female and male students have different motivation profiles on average with interest being variable according to the course topics [34]. As the course we sampled was a required course for first-year engineering students one might expect the students in the course to be about equally interested in the topics being covered. In addition, research has shown that engineering students generally choose to study engineering for reasons that do not differ largely by gender [16], [35].

Table 1: Results of the Jones MUSIC Model of Academic Motivation Questionnaire and the associated Cohen’s D Effect Sizes Organized by Gender

Motivational Construct	Male		Female		Effect Size (Cohen’s D)
	Score	Std Dev	Score	Std Dev	
Empowerment*	4.36	1.04	4.76	0.87	0.41
Usefulness**	4.02	1.14	4.51	0.84	0.50
Success**	4.78	0.98	5.24	0.71	0.53
Interest	3.98	1.18	4.23	0.99	0.23
Caring*	5.10	0.87	5.42	0.69	0.42

*Found to be statistically significant for: * $p < 0.05$; ** $p < 0.01$;*

The empowerment construct, meant to represent the elements of choice and control in academic settings, was found to be significantly ($p < 0.05$) different for males and females. This is consistent with the results from Rodriguez & Esparrago [21]’s study which used the intrinsic motivation inventory to determine that male and female students have significant differences in how they are motivated by choice. Their study, which used a pretest/posttest design to study the impacts of a multinational design project on motivation, found that female students did not experience a reduction in their choice score after the design project. It is possible that the results of the current study describe consistency in the female student’s motivational scores alongside a decrease in overall academic motivation for males although this cannot be determined for certain since no academic motivation data was collected at the onset of the semester.

It is not unusual for the results of a gamified intervention to benefit one subgroup of the class more so than others. For example, female students have reported benefits from the recognition that gamified systems provide through the reward system [10]. Evidence exists that show females are also motivated by an additional social factor that male students are less likely to benefit from overall [10], [36]. These forms of interactions are thought to be a major factor affecting the caring and success motivational constructs included within the MUSIC model. Similar effects may be present here through the leaderboard, achievements, and personalized grader feedback that Rezzly provided.

In the present study, female students were found to have higher academic motivation overall at the completion of the semester although it is yet unclear exactly how the gamification platform may have contributed to this result. Future work should explore whether this is a direct effect of

the gamification platform or could be due to confounding differences such as behavior, which will be discussed in the next section.

Research Question 2: What effects does gender have on submission behavior in an online gamified homework portal?

To address how submission behavior was impacted by student gender, gamification profiles were generated and analyzed. These results are presented in Table 2. It was found that the majority of students fell into the consistent category regardless of gender with 61% of male students and 69% of female students exhibiting this behavior profile. It appears that neither male nor female students were more likely to exhibit any of the gamification behaviors as no statistical differences were found in these gamification profiles when analyzed by gender.

Table 2: Gamification profiles for First-Year Engineering Students Completing Rezzly

Profile	Total (n=214)	Total (%)	Males (n=165)	Males (%)	Females (n=49)	Females (%)
Disheartened	9	4.21	9	5.56	0	0
Halfhearted	9	4.21	8	4.94	1	2.04
Late Awakener	43	20.09	35	21.6	8	16.33
Consistent	133	62.15	99	61.11	34	69.39
Achiever	4	1.87	3	1.85	1	2.04
Strategic	16	7.48	11	6.79	5	10.2

Interestingly, the only disheartened students were males. The halfhearted students had a similar distribution within the entire population with males being twice as likely to display halfhearted behavior than females when accounting for differences in sample size. While gender effects may exist in this difference, the relatively low sample size does present a limitation to this result.

Behavioral profiles were more broadly categorized as favorable and unfavorable behaviors. Favorable behaviors (consistent, strategic, achiever) are behavioral profiles in which students meet the final XP benchmark on the system. Conversely, unfavorable behaviors (disheartened, halfhearted, and late awakener) are defined by a final XP that does not reach the benchmark. Both male and female students were more likely to display favorable behavior, as shown by strategic, achiever, or consistent gamification profiles, in the Rezzly platform as shown in Table 3. However, female engineering students were more likely to be exhibiting favorable behaviors than male engineering students although these results did not quite reach statistical significance with a p-value of 0.073.

Table 3: Percentage of Male and Female Students Exhibiting Favorable and Unfavorable Gamification Profiles.

Gender	Favorable (%)	Unfavorable (%)
Males	69.75	32.1
Females	81.63	18.37

There are a few possible reasons for the observed differences in male and female behavior on the gamification platform. A study done by Bonneville-Roussy et. al [37] examined connections between motivation, behavior under stress due to assessments, and the performance outcomes of students. In particular, it was found that male students that used disengagement strategies in situations of high academic stress were less likely to have positive performance outcomes. Benchmarks associated with the platform may create situations of high academic stress and cause disengagement strategies that negate the benefits of gamification. In contrast, female engineering students were more likely to display favorable behaviors, which may be related to previous findings that have reported female engineering students having a consistent motivation through the duration of difficult tasks [21]. This is similarly consistent with findings from Han-Huei Tsay et. al's [8] study that found that female students engaged with their gamified course significantly more than male students. This is one possible explanation for the tendency for female engineering students to complete self-paced assignments while exhibiting favorable behaviors.

Limitations

A limitation of our study includes its specific focus on motivation as a potential driver for the behaviors observed within the online gamification platform as a result of gender. In addition, this study was limited to a focus on male and female genders due to the sample sizes represented within the population. The number of females participating in this study representing a small sample (n=49) also creates difficulties when profiling students based on behavior. The lack of disheartened and halfhearted female students may change when observing larger, more diverse populations.

Conclusion

Gamification is a growing trend in education practice that many find promising for its ability to positively influence students' motivation. The results in this study have implications for the development of gamified homework platforms in undergraduate engineering programs. For instance, it was found that female students appear to have both high academic motivation and favorable submission behaviors within the platform. Females had significantly higher motivation scores for the empowerment, usefulness, success, and caring constructs. However, some aspects of student academic motivation and behavior were found to be independent of gender. The majority of students displayed consistent and favorable behavior throughout the course. In addition, the interest scores were not statistically significant and did not have an effect size indicative of differences between the male and female students. Due to the focus on engineering students, it was expected that interest would be unrelated to gender and tied more strongly

towards the choice to pursue an engineering major. Intentional design of future gamified platforms or similar educational tools to be used in engineering education should take into account that gender may be a worthwhile consideration when designing platform elements to motivate based on interest.

Overall, the results presented in this study suggest that gamification is potentially a valuable tool for motivating female engineering students. In addition, the behavior displayed throughout the course was largely favorable. The extent to which students are consistent within the gamified platform provides further insight to how engineering students engage with gamified assignments. While the present study demonstrates the effectiveness of gamification as both a learning management system and motivational tool, additional research should be conducted prior to a full endorsement of gamified homework as a valuable tool for improving inclusivity among engineering classrooms.

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