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Article

What's in Their Words? How STEM Game Design Participants Discuss Their Projects, Motivation, and Success Differently

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Abstract: This study explored whether participation in a high school STEM game design enrichment program influenced students' discussions of project goals, motivation, and success. Seventeen high school students were included in the study, seven participated in the game design program, while ten were traditional students. Post-interviews were conducted using a semi-structured protocol in order to capture students' lived experience in a rich, meaningful way. Transcripts were qualitatively coded by two researchers. Connections between codes were analyzed using epistemic network analysis. Based on experience grouping, we investigated whether there was a difference in how students discussed (1) their projects? (2) their motivation? (3) their success? First, our findings revealed that traditional students discussed performance goals, while game design participants discussed learning goals. Second, game design participants discussed intrinsic motivation while traditional students discussed extrinsic motivation. Third, game design participants discussed persistence in relationship to their success; traditional students did not attribute their success to persistence. Overall, our combined results indicate that traditional students were performance-oriented, while game design participants were mastery-oriented. Designing STEM games is one potential method for helping students develop the mastery orientation that they need for success in future STEM careers and for their future in general.

Keywords: Mastery, Performance, Goal orientation, STEM, Game design, Persistence, Motivation

1. Introduction

The STEM pipeline is the educational pathway that takes students from early education through high school, college, and into science, technology, engineering, and mathematics (STEM) careers. In the United States, few students stay through the entire STEM pipeline (Chen, 2015; Potvin & Hasni, 2014) which is a detriment to the caliber of the STEM workforce.

There are noticeable leaks in the pipeline along the way. Despite a natural and intrinsic interest in STEM during infancy (Gopnick et al., 1999), students can form negative emotional responses towards STEM early in their schooling and these responses persist (Murphy et al., 2019). As students enter adolescence, their interest in STEM drops precipitously declining dramatically between elementary school and secondary school (Potvin & Hasni, 2014). Even if students graduate high school with STEM career intentions, it does not guarantee they will enter the profession. Many students who start their college education as STEM majors switch to non-STEM majors before getting their degree (Chen, 2015).

Fortunately, we know how to help students stay in the STEM pipeline and achieve success. Research shows that there is a link between a mastery orientation and high persistence in STEM (Murphy et al., 2019). Within the workforce, STEM professionals who have a mastery orientation are more productive and successful than those with a performance orientation (Hazari et al., 2010). Due to overemphasis on discrete facts and a lack of engaging, authentic experiences (National Research Council, 2012), educational inventions that promote a mastery orientation within STEM are few and far between; experts argue that we need to create and implement learning approaches within STEM that will help students develop a mastery orientation (Henry et al., 2019).

In the sections that follow, we will make the case that there are key differences between mastery-oriented students and performance-oriented students and traditional instructional environments emphasize a performance orientation while designing STEM games emphasizes a mastery orientation. We will argue that designing STEM games is an effective approach to STEM learning that has the potential to shift students' focus from performance goals to learning goals, increase their intrinsic motivation, and help them develop persistence. We will report on a research study exploring the student experience of designing STEM games as it compares to traditional school projects. Since a significant number of students drop out of the STEM pipeline, the goal of this study was to investigate whether designing STEM games helps students develop the mastery orientation necessary for staying in the STEM pipeline.

1.1. Orientation Differences

There are key differences between mastery-oriented students and performance-oriented students. Some of these differences can be seen through the goals that students have (Pintrich, 2000), the type of motivation that they display (Deci & Ryan, 2000; Elliot & Church, 1997), and whether they can persist through challenging tasks (Dweck, 1986; Linnenbrink, 2005).

1.1.1. Project Goals

When students approach or engage in a task, they are concerned with certain reasons or purposes that define their goals (Pintrich, 2000). Some students have learning goals and are focused on learning new skills and improving their competence. These students are mastery-oriented. Other students have performance goals and are focused on seeking evidence of performing better than others (Dweck, 1986; Dweck & Leggett, 1988). These students are performance-oriented.

In the classroom context, Linnenbrink (2005) found that a focus on learning goals was beneficial to achievement while a focus on performance goals was detrimental to achievement. Students with learning goals not only have deeper cognitive engagement and higher learning performance (Wolters et al., 1996) but also higher confidence in the intellectual abilities (Koestner & Zuckerman, 1994). When compared to students with performance goals, students with learning goals consistently demonstrate higher achievement even when prior achievement and demographics are included as controls (Keys et al., 2012). Essentially, student goals have a consistent and predictable relationship with classroom achievement, and students with a focus on learning goals have the most positive outcomes (Wolters et al., 1996).

1.1.2. Motivation

Motivation is a key construct in education; “students will learn only if they are motivated” (Csikszentmihalyi *et al.*, 1993, p. 195). Motivation can be intrinsic or extrinsic. According to Deci and Ryan (2002), when people are intrinsically motivated, the initiation of the behavior comes from within themselves and they find satisfaction inherent in the activity. These students are generally mastery-oriented. When people are extrinsically motivated, the initiation of the behavior comes from outside themselves and their satisfaction is dependent on contingent outcomes. These students are generally performance-oriented.

In the classroom context, students with high levels of intrinsic motivation demonstrate superior performance on a number of educational variables such as academic achievement, classroom functioning, and performance on intelligence tests (Allen et al., 2005). Unfortunately, students in traditional school environments report low levels of intrinsic motivation (Rathunde & Csikszentmihalyi, 2005). Academically, intrinsic motivation is important because it has been shown to provide an early foundation that benefits children’s motivation throughout adolescence and during adulthood (Gottfried et al., 2017). Intrinsic motivation is an important attribute for students; it not only benefits academic achievement in adolescence but also education attainment in adulthood (Gottfried *et al.*, 2017).

1.1.3. Persistence

Persistence is an individual quality that enables a person to continue doing something despite difficulties and it is shaped by the expectation of success (Eccles & Wigfield, 2002). When students have higher levels of expectancies for success, they are more likely to persist and demonstrate higher achievement (Bandura, 1977, 1997; Eccles, 1983; Wigfield & Eccles, 1992). Mastery-oriented students generally demonstrate higher persistence, while performance-oriented students demonstrate lower persistence.

In the classroom context, persistence serves as a building block for academic achievement. Research has shown that persistence is related to academic achievement, such as exam performance (Elliot et al., 1999). Persistence has also been shown to be a strong predictor of adolescent grade point average (Andersson & Bergman, 2011). On the Third International Mathematics and Science Study (TIMSS), researchers reported that students’ task persistence had a predictive relationship with national mean scores (Boe et al., 2002). Ability to persist at a task in adolescence is even related to educational attainment during adulthood (Andersson & Bergman, 2011).

1.2. Differences in Instructional Approaches

1.2.1. Project Goals

In traditional school environments, performance goals are promoted over learning goals. Typically, schools use a grading structure to provide feedback on how well students perform. Experts indicate that grades tend to reflect a student's abilities rather than a student's learning (Schinske & Tanner, 2014); therefore, grading promotes performance goals over learning goals. Those students who have performance goals are also focused on their ability in comparison to others, and grades give students a concrete way to their judge their ability in relationship to others. This social comparison can be very detrimental to students—it can hamper students' judgements of themselves (Ames, 1992).

Ames (1992) argues that goal orientation can be shaped by the learning environment. Designing games is a unique learning environment that highlights learning goals over performance goals. When students design games, there is a focus on learning because designing games exposes students to content in a whole new way. As stated by Macklin, Martin, and Dikkers (2012), "if you want to truly understand a topic, design a game for it" (p. 142). The designers need to know the content well in order to create the game. Research has shown that students will engage in extensive research in order to improve their game design (Owston et al., 2009).

When students create games—with support from teachers and the school culture in terms of content accuracy, time allowed, and recognition of the work involved—students become engaged with the content in a more deep and meaningful way. Game designers need not only a baseline understanding of their subject matter but also a sense of the connections between different areas within the subject. Research has shown that active involvement in the design process actually increases learners' understanding of the content embedded in the game (Lamb et al., 2015).

1.2.2. Motivation

In traditional school environments, there is a focus on extrinsic motivation rather than intrinsic motivation. There can be benefits to extrinsic rewards and performance goals (Hidi & Harackiewicz, 2000); however, despite good intentions, they can have detrimental effects when applied to all students given their varying abilities and interest levels (Ames, 1992). Research shows that expected tangible rewards, such as grades and test scores, can undermine intrinsic motivation (Deci & Ryan, 2002). Thus, as schools place external expectations on students in the form of performance goals and grades, it can decrease students' intrinsic motivation (Deci et al., 2001).

Intrinsic motivation can be enhanced by providing students with a choice—about what to do for a project or how to do it (Deci & Ryan, 2002). When students design games, they are empowered to make choices and decisions. Research has shown that when students design games they are motivated by the development process itself (Owston et al., 2009). Their motivation is intrinsic because it comes from within themselves.

Furthermore, when students work on a game design, they may feel a sense of agency. When students have agency, they have a perception of control and that sense of control is essential to motivation (Bandura, 2006). When students are given agency, they show a willingness to work hard for intrinsic rewards (Rector-Aranda & Raider-Roth, 2015). In a game design project, the intrinsic reward is getting the game to work.

1.2.3. Persistence

In traditional school environments, certain teaching practices can have a negative impact on student's ability to persist; students develop a learned helplessness (Diener & Dweck, 1978). When tasks require persistence, students with learned helplessness feel that they cannot overcome the challenge (Abramson et al., 1978). When students perceive their teachers as controlling, there is a greater chance they will feel a sense of learned helplessness. (Filippello et al., 2020). Also, students are more likely to persist when they think their schoolwork is important and useful (Pokay & Blumenfeld, 1990). Unfortunately, for many students, school is full of drudgery and boring seatwork (Gatto, 2009).

Unlike traditional teaching practices that can be too controlling, students designing games work without much support (Allsop, 2016); therefore, they feel a greater sense of autonomy and a lesser sense of learned helplessness. Authoring computer games can give students a sense of ownership, which may help them persist through the design process (Ke, 2014). Rather than feeling as though they cannot overcome the challenge, designing a game becomes a challenge that they are motivated and enthusiastic to overcome (Robertson & Howells, 2008). When students design games, research has shown that they will engage with the project for long periods of time and they are motivated to complete it (Owston et al., 2009).

Furthermore, creative production can be empowering. Students report more intention to persist during creative challenges than academic challenges (Hoffmann et al., 2016). Essentially, young people want to persist through the creative process and finish their project (Ito *et al.*, 2010).

1.3. Research Questions

We need to provide high school students with opportunities where students can focus on learning goals, increase intrinsic motivation, and learn to persist through challenges in order to succeed. Designing games has the potential to help students build out these skills; however, Denner, Campe, & Werner (2019) confirmed that there is a lack of research comparing the experience of designing computer games to other conditions, particularly traditional instruction. In project GRADUATE, high school students became STEM game creators while their teachers became the facilitators of content and pedagogy, ensuring misconceptions were not perpetuated in the games. To determine how designing STEM games differed from traditional school projects, we interviewed GRADUATE participants and traditional students about a memorable project they completed during the school year. The following questions guided our investigation. Based on experience grouping, is there a difference in how students 1) discussed their projects? 2) discussed their motivation? 3) discussed their success?

RQ1: Do GRADUATE participants discuss their projects differently than traditional students, and if so, how?
H1: GRADUATE participants will discuss learning goals while traditional students will discuss performance goals.

RQ2: Do GRADUATE participants discuss their motivation differently than traditional students, and if so, how?
H2: GRADUATE participants will discuss intrinsic motivation while traditional students will discuss extrinsic motivation.

RQ3: Do GRADUATE participants discuss their success differently than traditional students, and if so, how?
H3: GRADUATE participants will discuss success in light of their persistence while traditional students will not.

2. Materials and Methods

2.1. Setting and Sample

Two high schools in a rural Mid-Atlantic region of the United States participated in the study. Both high schools had high dropout rates of approximately 60 percent. A small subset of students from each high school participated in an enrichment program called GRADUATE (Games Requiring Advanced Developmental Understanding Around Technological Endeavors). Approximately 80 students participated in GRADUATE where they learned to develop “serious educational games” with a focus on STEM education. Participants were tasked with storyboarding their games and then building a functional game. For the story, students were expected to create an exciting narrative, complete with interesting characters and a compelling plot line. To build the game, students used customized software. The game design software did not require sophisticated programming or animation—in fact, it simplified the process for the designer. However, basic programming was necessary.

As a foundation, the science teachers developed lesson plans about the environment and were trained to use the game design software over the summer. Then, during the school year, the teachers implemented their lesson plans and worked with the students to create games based on the environmental concepts they had learned. Under the guidance of university doctoral students and their science teachers, over 25 students were able to finish their games. Completed games tackled science topics ranging from sickle cell anemia to diabetes and medical ethics to neuroscience.

At the end of the school year, students were randomly selected to participate in detailed, semi-structured interviews about their most memorable school project from that year. A total of 17 students were interviewed. Seven of the students (3 girls, 4 boys) participated in the GRADUATE enrichment program. The remaining ten students (5 boys, 5 girls) did not participate in GRADUATE.

2.2. Data Collection

Data were collected via individual interviews based on an interview protocol. There were two separate interviewers who both abided by the same protocol. The protocol helped ensure specific and consistent topics were addressed across all students; however, if the researcher deemed an opinion particularly important, the researcher could draw out the explanation and better understand. Interviews lasted anywhere between 5 minutes and 25 minutes. The average duration of an interview was approximately 10 minutes. All interviews were audio recorded and transcribed.

2.3. Data Analysis

To analyze the interview data, there were several readings of the transcripts. Employing the constant-comparative method (Glaser & Strauss, 1967), the lead researcher reviewed transcripts by starting with open coding. During this phase of coding, memos were recorded to document potential connections between codes. Thirty-two codes were generated. Through peer debriefing, the authors collapsed the list of codes into nine vital codes for detailed analysis. In relationship to the project (#4), students talked about knowledge (#5) and confidence (#6). In relationship to motivation (#1), students discussed themselves (#2) and school (#3). In relationship to success (#7), students talked about learning (#8) and persistence (#9). To check for inter-rater reliability, two authors each coded 20% of the utterances. Cohen's kappa was calculated for each code: project (0.84), knowledge (0.77), confidence (0.74), motivation (0.87), myself (0.93), school (0.90), success (0.71), learning (0.89), and persistence (0.84). According to McHugh (2012), agreement was at least moderate for all codes and overall interrater reliability (0.83) for the study was strong; therefore, one researcher coded the remaining data.

In total, over 735 utterances were coded using the nine vital codes. For each research question, we used epistemic network analysis (Shaffer, 2006; Shaffer, 2017) to analyze the coded utterances. Epistemic network analysis (ENA) offers two distinct advantages: it accounts for connections *between* codes and can statistically compare those connections from one group to that of another group.

First, unlike simplified coding and counting strategies, ENA investigates connections *between* codes represented in the data (Shaffer et al., 2016). With the ENA strategy, each utterance from an interviewee is important both alone and in conjunction with the immediately previous statements. Since ENA investigates code connection *between* utterances, research has shown that it exposes more nuanced differences than coding and counting (Csanadi et al., 2018; Swiecki et al., 2020).

Second, using the code connection, ENA generates network models (Shaffer *et al.*, 2016) that can be statistically compared. To create each model, ENA utilizes the moving stanza window method (Siebert-Evenstone *et al.*, 2017; Shaffer, 2017). First, ENA captures code connections within each utterance. Then, ENA captures code connections between the referent utterance and those within a small window of previous utterances. All of those code connections are then displayed as a network model where the codes are the nodes in the model and the strength of each connection is summarized as a centroid. To determine if there is a difference between two network models, the centroid for each model is compared using a t-test. For further discussion of ENA, please refer to Bressler et al. (2019).

In order to understand whether there were differences in how participating students discussed their orientation to the project, their motivation, and their success, we compared two ENA models for each research question. The first model combined all the code connections from the GRADUATE participants, or the *treatment* group. The second model combined all of the code connections from the non-GRADUATE participants, which was deemed the *control* group. The centroid from each model was compared along the x-axis using a two-sample t-test assuming unequal variance. If differences existed, then we investigated what code connections were causing the difference.

3. Results

All 17 interviewees were asked to talk about a memorable project from their school year that made them feel proud. Using the post-interview data, we used ENA to explore how the discussions differed between GRADUATE participants and traditional students in a comparison group. Even though what project the students chose to talk about was irrelevant to the study, it is worth noting that all of the GRADUATE participants mentioned the game design project as the project which garnered the most pride. The traditional students spoke about a variety of project types including science projects, engineering projects, and history projects.

3.1. Project Goals (Research Question #1)

For the first research question, we wanted to know if GRADUATE participants discussed their projects differently than traditional students. To answer this question, we created an ENA model, and connections between codes for GRADUATE participants (Treatment) were compared to connections between codes for traditional students (Control). Figure 1 shows the plotted points for treatment participants (red) and control students (blue). The plotted points of collective responses to each interview question are the dots. Statements made by respondents within the treatment group are indicated by red dots, while statements made by respondents within the control group are indicated by blue dots. Each interview included multiple questions, so each group is represented by multiple dots. The average of these points, or centroid, is shown as a square with a 95% confidence interval for each dimension represented by the rectangular outline.

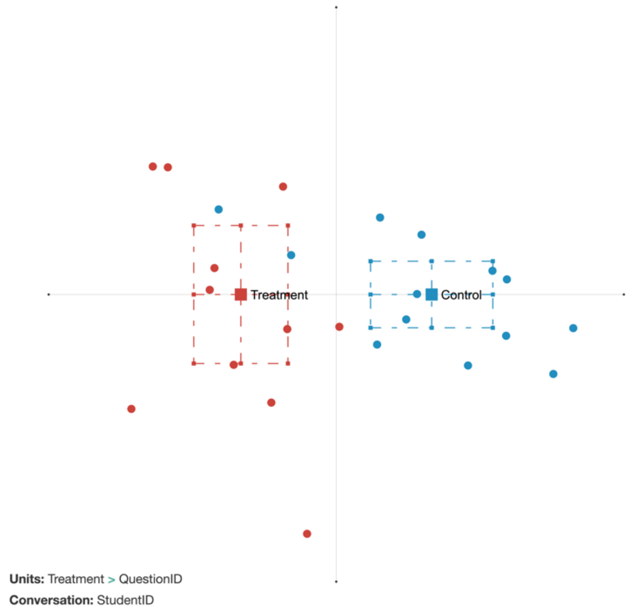


Fig.1. Comparison of project discussion for treatment (red) and control (blue).

ENA explained 65.6% of the variance in coding co-occurrences along the x-axis and 29.4% of the variance on the y-axis. A two-samples t-test (assuming unequal variances) was used to determine if there was a statistically significant difference between the mean for each experience group. At the alpha = 0.05 level, the t-test ($t(22.53) = -5.39$; $p < 0.01$) revealed a statistically significant difference between the treatment group ($M = -0.97$, $SD = 0.80$, $N = 13$) and the control group ($M = 0.97$, $SD = 1.03$, $N = 13$) along the x-axis. Cohen's d was equal to 2.11, which was interpreted as a large difference between the experience groups. A post-hoc Bayesian analysis (Tutwiler, 2019) with a regularizing Cauchy prior set to 0.707 indicates a median effect size of about 1.3 with a 95% Credible Interval ranging between 0.5 and 2.2 (Fig. 2a). The data strongly ($BF_{10} > 10$) support the hypothesis that the mean scores are not equal across a wide range of potential prior distributions (Fig. 2b).

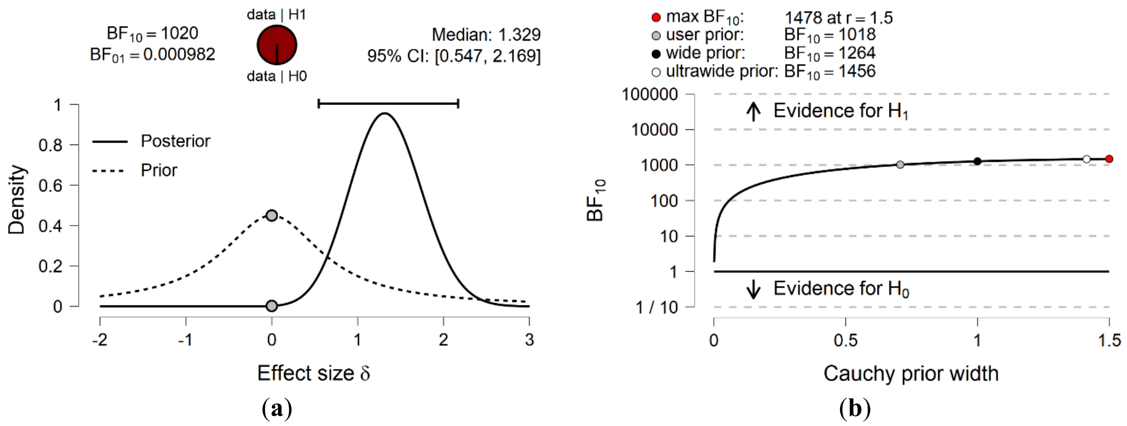
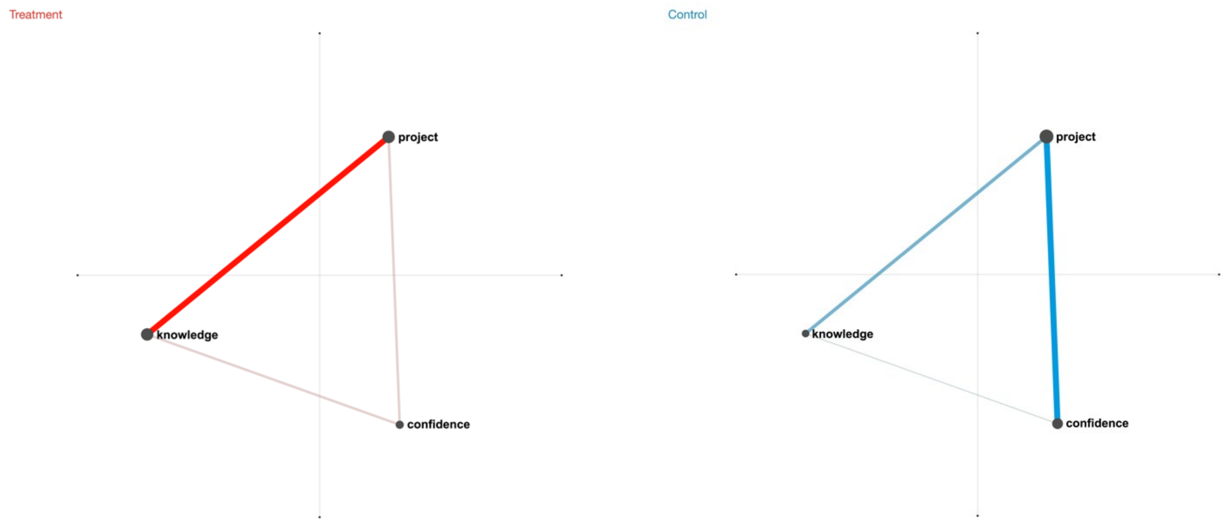


Fig. 2. Post- hoc Bayesian estimates of (**a**) effect-size; (**b**) robustness across priors for RQ1.

Along the x-axis, there was a statistically significant difference in the network connections present among the treatment group and those of the control group. To determine why this difference occurred, we analyzed the individual network diagrams. Investigating the strength of the connections between codes can reveal what codes are causing each centroid to shift left or right. The individual diagrams are shown in Fig. 3. The diagram for the treatment group has relatively weak connections between *knowledge* and *confidence* along with *project* and *confidence* therefore the line weights are lighter. In contrast, there is a thick, dark red line between *knowledge* and *project* indicating a very strong connection. Since the connection between *knowledge* and *project* is so strong, it shifts the centroid to the left on the x- axis. The diagram for the control group shows that the strongest connection is between *project* and *confidence*. Since these codes on located to the right on the x-axis, the strength of this connection shifts the control group's centroid to the right.

As shown in Fig. 3 (b), the strong connection between the *project* code and the *confidence* code indicates that the traditional students in the control group expressed confidence around certain aspects of the project. For example, when talking about their most memorable project of the school year, one student said, “she saw that I was really good with working with computers" and another student said, “so many people told me it was phenomenal." It’s worth noting that these students talked about their competence in light of getting favorable feedback on their projects.



(**a**) (**b**)

Fig. 3. Individual networks highlighting connections for project discussion for (**a**) treatment model; (**b**) control model.

While the control group expressed confidence around certain aspects of their projects, this was not true for the GRADUATE participants in the treatment group. There were no strong connections to the *confidence* code because students in the treatment group lacked confidence in the coding aspect of designing a serious educational game. For example, one GRADUATE participant said, "the coding aspect was a little hard to learn" while another one said, "I had to get with somebody to help me work the coding and stuff.”

In contrast to the control group, the treatment group had a strong connection between the *project* code and the *knowledge* code. This indicates that those in the treatment expressed that they gained knowledge through working on the project. Some participants stated that they gained content knowledge while working on their STEM game, such as, "I learned a lot of environmental stuff." Other participants discussed gaining knowledge of coding, for example, "coding…isn’t really that easy, but once you figure it out, it’s an enjoyable thing to learn." When GRADUATE participants talked about their STEM game projects, they seemed excited about the fact that they learned something new and gained coding skills.

3.2. Motivation (Research Question #2)

For the second research question, we wanted to know if GRADUATE participants discussed their motivation differently than traditional students. To answer this question, we created another ENA model with a different set of codes, and connections between the codes for the treatment group were compared to connections between codes for the control group. Fig. 4 shows the plotted points for the treatment group (red) and the control group (blue). The centroid for these points is displayed as the square in the middle; the rectangular outline represents the 95% confidence interval for each dimension.

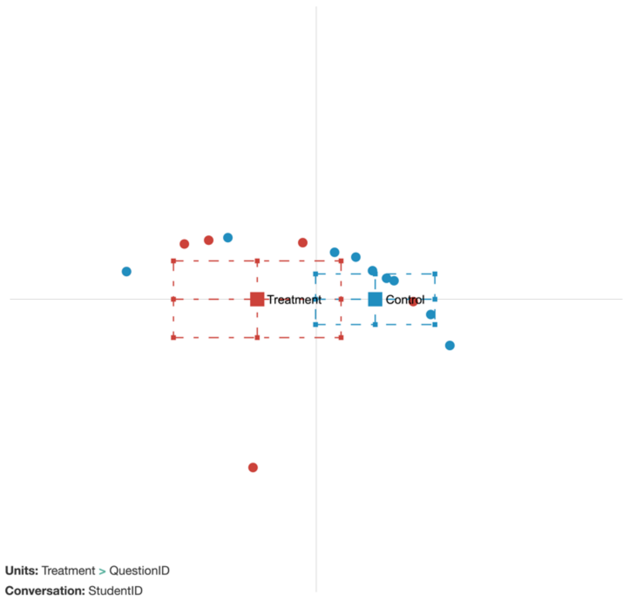
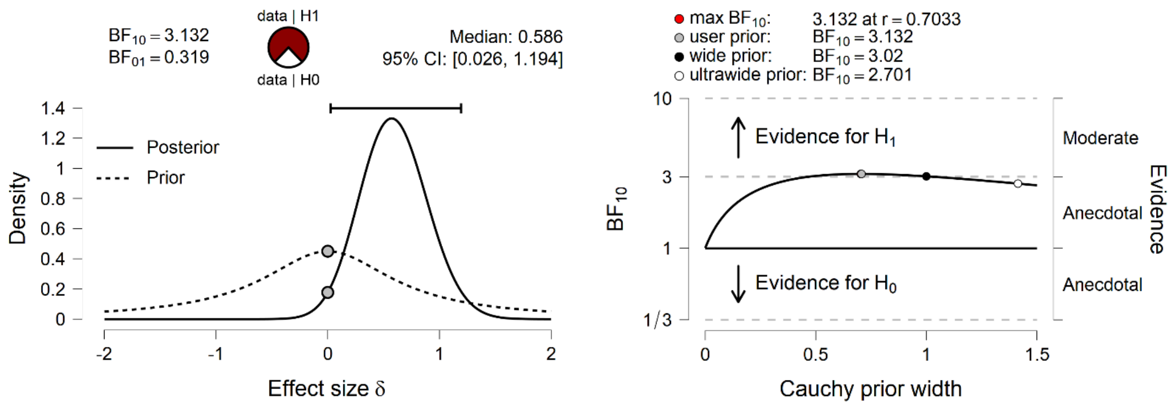


Fig. 4. Comparison of motivation discussion for treatment (red) and control (blue)

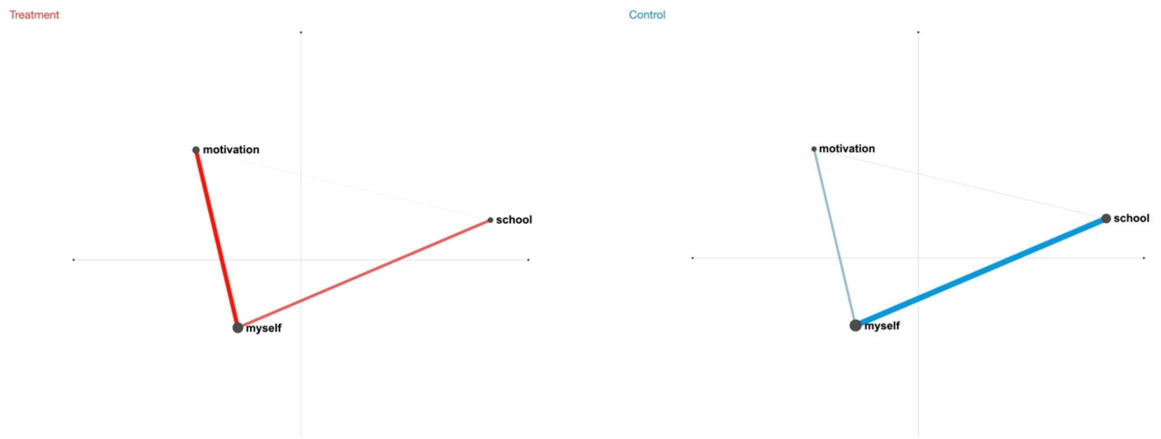
ENA explained 84.6% of the variance in coding co-occurrences along the x-axis and 13.4% of the variance on the y-axis. A two-samples t-test (assuming unequal variances) was used to determine if there was a statistically significant difference between the mean for each experience group. At the alpha = 0.05 level, the t-test ($t(21.68) = -2.50$; $p = 0.02$) revealed a statistically significant difference between the treatment group ($M = -0.32$, $SD = 0.74$, $N = 13$) and the control group ($M = 0.32$, $SD = 0.53$, $N = 13$) along the x-axis. Cohen's d was equal to 0.98, which was interpreted as a large difference between the experience groups. A post-hoc Bayesian analysis (Tutwiler, 2019) with a regularizing Cauchy prior set to 0.707 indicates a median effect size of about 0.6 with a 95% Credible Interval ranging between 0.03 and 1.2 (Fig. 5a). The data moderately ($BF_{10} > 3$) support the hypothesis that the mean scores are not equal across a wide range of potential prior distributions (Fig. 5b).



(a) (b)

Fig. 5. Post- hoc Bayesian estimates of (**a**) effect-size; (**b**) robustness across priors for RQ2.

Similar to the results for the first research question, there was a statistically significant difference in the network connections present among the treatment group and those of the control group along the x-axis. To determine why this difference occurred, we analyzed the individual network diagrams. The individual diagrams are shown in Figure 6. The diagram for the treatment group shows that the strongest connection is between *motivation* and *myself*. Since these codes on located to the left on the x-axis, the strength of this connection shifts the treatment group's centroid to the left. The diagram for the control group shows that the strongest connection is between *myself* and *school*. Since the *school* code is located to the right on the x-axis, the strength of this connection shifts the control group's centroid to the right.



(**a**) (**b**)

Fig. 6. Individual networks highlighting connections for motivation discussion for (**a**) treatment model; (**b**) control model.

The strong connection between the *myself* code and the *school* code indicates that the traditional students in the control group discussed school related factors. For example, when discussing why they were proud of their projects, one student from the control group said, "I got a good grade for it" and another student said, "my teacher told me I did a great job." It's worth noting that the school related factors such grades and teachers are external factors.

In contrast to the control group, the treatment group had a strong connection between the *motivation* code and the *myself* code. This indicates that those in the treatment expressed that they were motivated by internal factors such as wanting to do well. For example, one student who completed the game design project said, "Throughout my game…I wanted to do a good job." Another student said, "like the games that are out today, I want to make it more like that."

3.3. Success (Research Question #3)

For the third research question, we wanted to know if GRADUATE participants discussed their success differently than traditional students. To answer this question, we created a third ENA model with a different set of codes, and connections between the codes were compared across groups. Fig. 7 shows the plotted points and the centroid for the treatment group (red) and the control group (blue).

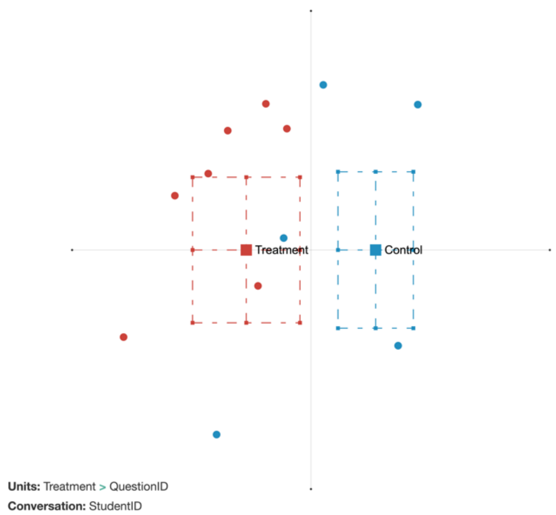
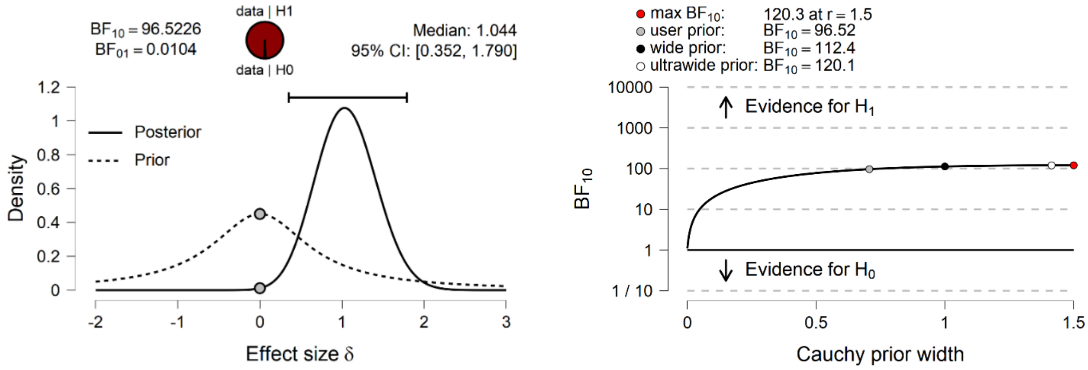


Fig. 7. Comparison of success discussion for treatment (red) and control (blue)

ENA explained 29.2% of the variance in coding co-occurrences along the x-axis and 43.7% of the variance on the y-axis. A two-samples t-test (assuming unequal variances) was used to determine if there was a statistically significant difference between the mean for each experience group. At the alpha = 0.05 level, the t-test ($t(21.51) = -4.30$; $p < 0.01$) revealed a statistically significant difference between the treatment group ($M = -0.54$, $SD = 0.74$, $N = 13$) and the control group ($M = 0.54$, $SD = 0.52$, $N = 13$) along the x-axis. Cohen's d was equal to 1.69, which was interpreted as a large difference between the experience groups. A post-hoc Bayesian analysis (Tutwiler, 2019) with a regularizing Cauchy prior set to 0.707 indicates a median effect size of about 1.0 with a 95% Credible Interval ranging between 0.4 and 1.8 (Fig. 8a). The data strongly (BF_{10} > 10) support the hypothesis that the mean scores are not equal across a wide range of potential prior distributions (Fig. 8b).



(a) (b)

Fig. 8. Post- hoc Bayesian estimates of (**a**) effect-size; (**b**) robustness across priors for RQ3.

Similar to the results for the first two research questions, there was a statistically significant difference in the network connections present among each group along the x-axis. To examine why this difference occurred, we analyzed the individual network diagrams. The individual diagrams are shown in Fig. 9. The diagram for the treatment group shows that the strongest connection is between *persistence* and *success*. Since the *persistence* code is located to the left on the x-axis, the strength of this connection shifts the treatment group's centroid to the left. The diagram for the control group shows that the strongest connection is between *learn* and *success*. Since these codes on located to the right on the x-axis, the strength of this connection shifts the control group's centroid to the right.

(a) (b)

Fig. 9. Individual networks highlighting connections for success discussion for (**a**) treatment model; (**b**) control model.

The strong connection between the *learn* code and the *success* code indicates that individuals in the control group learned that they could be successful. For example, when reflecting on their projects, one individual said, "It was actually good" and another individual said, "That was the first project I have ever done that I really felt like I could be proud of it." It's worth noting that there are extremely weak, practically non-existent connections to the persistence code.

In contrast to the control group, the treatment group had a strong connection between the *persistence* code and the *success* code. This indicates that those in the treatment expressed that their success—and possibly enjoyment—was due in part to their persistence. For example, one GRADUATE participant stated, " I did like the gaming project because I have never worked so hard in my entire life." Another GRADUATE participant said, "I would work until I was satisfied with what I had accomplished that day." It is also worth noting that there was some strength to the connection between the *persistence* code and the *learn* code, whereas in the control group, this connection was virtually non-existent. Some students in the treatment group seemed to express that they learned the value of hard work. For example, one interviewee mentioned that "I just learned that I needed to just put my effort into it."

4. Discussion

In this research study, we examined interview data from students who did and did not participate in the GRADUATE program in order to determine whether there were differences in how STEM game design participants discussed their projects, their motivation, and their success. The data were consistent with our hypotheses. According to our findings, GRADUATE participants discussed learning goals, intrinsic motivation, and success as a result of their persistence. Traditional students discussed performance goals and extrinsic motivation; they did not mention persistence in relationship to their success.

4.1. Project Goals

For the first research question, we used ENA and determined that GRADUATE participants discussed their projects differently than traditional students. Traditional students expressed confidence around their projects especially in relationship to positive feedback. GRADUATE participants lacked confidence but talked about gaining knowledge. These patterns in the data indicated that traditional students were focused on performance goals, while GRADUATE participants were focused on learning goals.

Students with performance goals focus on their ability and seek confirmation of it (Ames, 1992; Dweck, 1986). When the traditional students in this study spoke about their projects, they seemed to have a performance goal in mind. First, they discussed confidence and students with a performance goal need to be confident in their ability before pursuing judgement (Dweck, 1986). Second, they discussed their competence in conjunction with favorable feedback and students with a performance goal are focused on getting positive feedback about their competence (Dweck, 1986). Finally, the traditional students spoke about projects that were in their comfort zone and performance-focused students can better ensure success when they chose easier tasks (Dweck, 1986).

Students with learning goals aim to increase their competence often by learning something new (Dweck, 1986). When the GRADUATE participants in this study spoke about their projects, they seemed to have a learning goal in mind. Unlike the traditional students, the GRADUATE participants did not display confidence. Since a student with a learning goal is focused on understanding new material, they do not yet display confidence; in fact, such students are actually willing to display ignorance (Dweck, 1986) and some of the GRADUATE participants did discuss ignorance. When the GRADUATE participants spoke about their projects, they focused on how they gained knowledge about content and coding, and students with learning goals are trying to acquire new skills and knowledge (Dweck, 1986).

Prior research in game design supports this idea that game design shifts students' focus away from performance goals to learning goals. Kafai and Burke (2015) reviewed and synthesized 55 game design studies and found that making games changes students' attitudes related to the goals of the project. Schools generally orient students towards performance goals, expecting them to perform well on assessments. In turn, students seek immediate feedback in the form of a good grade. Whereas, after designing games, students seem to have a better grasp of the long-term learning benefits of the experience (Kafai & Burke, 2015).

4.2. Motivation

For the second research question, we used ENA and determined that GRADUATE participants discussed motivation differently than traditional students although based on our post-hoc Bayesian analysis, the evidence for this finding falls between anecdotal and moderate.

Traditional students mostly discussed school-related factors, such a getting a good grade or knowing that their teacher was pleased. GRADUATE participants did not reference school-factors as much; instead, they discussed themselves and their desire to do well. These patterns in the data indicated that traditional students were mostly extrinsically motivated, while GRADUATE participants were mostly intrinsically motivated.

For students with extrinsic motivation, the initiation of the behavior comes from outside themselves and their satisfaction is dependent on contingent outcomes (Deci & Ryan, 2002). Statements from the traditional students had a strong connection to the *school* code. Students spoke about getting a good grade; therefore, the initiation for the behavior seemed to come from outside themselves. They also spoke about pleasing the teacher indicating that their satisfaction was dependent on someone else. Our finding that traditional students discussed mostly school-related factors demonstrates that their motivation was mostly extrinsic.

For students with intrinsic motivation, the initiation of the behavior comes from within themselves and they find satisfaction inherent in the activity (Deci & Ryan, 2002). Statements from the GRADUATE participants indicated a strong connection between the *motivation* code and the *myself* code. Students spoke about how they wanted the project to turn out; there was little to no mention of school-related factors. In addition, they seemed to find inherent satisfaction within the activity because they expressed excitement about learning something new and gaining coding skills. Our finding that GRADUATE participants discussed mostly internal factors demonstrates that their motivation was mostly intrinsic.

Prior research in game design supports this finding that game design helps to increase student's intrinsic motivation. First, in a recent meta-analysis of 68 studies that focused on designing and programming computer games, Denner, Campe, & Werner (2019) determined that game design benefits students' motivation. In particular, the researchers found that when students receive scaffolded instruction, their intrinsic motivation increases. Second, Hwang, Hung, and Chen (2014) studied science students designing games and concluded that the game design task increased students' science learning motivation. Finally, An (2016) studied students designing games about communism and found that the game design experience increased students' motivation to learn game design and programming.

4.3. Success

For the third research question, we used ENA and determined that GRADUATE participants discussed success differently than traditional students. GRADUATE participants discussed persistence in relationship to their success. Traditional students discussed that they learned that they could be successful; however, they did not attribute their success to persistence. These patterns in the data indicated that traditional students took a performance approach to their achievement, while GRADUATE participants took a mastery approach.

When students take a performance approach, their ego is deeply involved (Ames, 1992); their satisfaction with the activity is derived from how well they performed (Dweck, 1986). Statements from the traditional students had a strong connection between the *learn* code and the *success* code. Basically, these students felt really good because they realized that they had succeeded. Also, overcoming obstacles is not in line with those who deeply care about their performance because difficulties can negatively impact a student's view of their ability (Dweck, 1986); therefore, the traditional students did not mention persistence in relationship to their success.

When students take a mastery approach, they are deeply invested in the task (Ames, 1992); their satisfaction with the activity is derived from how much effort they exerted (Dweck 1986). Statements from the GRADUATE participants had a strong connection between the *persistence* code and the *success* code. Basically, these students felt really good because they had worked really hard to succeed. Also, those who take a mastery approach are more likely to seek out challenges (Dweck, 1986) and demonstrate persistence towards their goals (Linnenbrink, 2005); therefore, the traditional students discussed persistence in relationship to their success.

Prior research in game design supports this finding that game design helps to students focus on effort and persist through challenges. First, Vos, Van Der Meijden, and Denessen (2011) compared students playing games to students creating games; they determined that those in the creation condition exerted more effort than those in the play condition. Second, Ke (2014) studied students creating games and frequently observed students putting a great deal of effort into their game designs. According to Ke (2014), the students' thinking was not only effortful, but they would persist at it. Finally, when Robertson and Howells (2008) studied a class of children making their own computer games, they noted that the students were particularly determined to persevere.

4.4. Student Orientations

When taken together, the findings from these three research questions indicate that GRADUATE students were mastery-oriented while the traditional students were performance-oriented. Mastery-oriented students are focused on learning goals (Pintrich, 2000), intrinsically motivated (Elliot & Church, 1997), and more capable of persisting through challenges (Linnenbrink, 2005); therefore, the GRADUATE participants were mastery-oriented. Performance-oriented students are focused on performance goals (Pintrich, 2000), extrinsically motivated (Deci & Ryan, 2000), and less capable of persisting through challenges (Dweck, 1986); therefore, the traditional students were performance-oriented.

Helping our students develop a mastery orientation is beneficial for several reasons. First, mastery-orientation consistently predicts achievement over performance-orientation (Keys et al., 2012). Second, students with a mastery-orientation often have a healthier relationship with failure; they are more likely to have positive emotions associated with failure (Tulis & Ainley, 2011) and they view challenges as problems that can solved with effort (Dweck & Leggett, 1988). Lastly, a mastery orientation is a good predictor of self-efficacy (Wolters et al., 1996). Essentially, students create and develop their self-efficacy beliefs largely through mastery experiences, such as designing games (Bandura, 1986, 1997). In fact, designing computer games as been shown to raise self-efficacy (Newton et al., 2020; Seaborn et al., 2012). A person's self-efficacy beliefs predict subsequent behavior better than their knowledge or prior attainments (Bandura, 1986).

4.5. Study Limitations

This study had several limitations. First, this is largely exploratory work because it is based on a single post-assessment: we only reported on post-interviews. Second, these findings are rigorous and can be replicated; however, they need to be cross validated with other measures in the same domain to confirm the findings. Third, there are assumptions within the analysis. The assumptions are embedded in the qualitative coding and in the online software package. These assumptions play a role in the patterns observed in the data. Before the findings can be deemed robust, they will need to be replicated using alternative approaches to discourse analysis, such as a quantitative method that simplifies complex relationships.

5. Conclusions

Experts argue that students need more learning approaches within STEM that will help them develop a mastery orientation (Henry et al., 2019). Our research shows that designing STEM games can offer this type of experience. Our findings demonstrate the potential for STEM game design experiences to help students focus on learning goals, find their intrinsic motivation, and persist through challenges which are important components of a mastery orientation.

Designing STEM games is challenging yet enjoyable (Newton et al., 2020). It enables students to be proficient producers in the digital world—and it is the process of production that offers the deepest learning benefits (Martinez & Stager, 2013). As Kafai (2006) has argued, "the greatest learning benefit remains reserved for those engaged in the design process, the game designers...the learner is involved in all the design decisions and begins to develop…new ways of thinking (p. 39)." By using STEM game design to support students in the development of their own ideas—hopefully—we can help them develop a mastery orientation which will serve them well not only in STEM but also in life.

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