Gamifying Engineering: Initial data and results from implementing a naval engineering video game (work in progress)

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Abstract

Future Leaders in Experience-based Engineering & Technology (FLEET) engages students in the engineering design process through shipbuilding. This program was funded by the Office of Naval Research so all components of the program were free, and yet we found numerous challenges that required we adapt our implementation strategies. Initially, usability studies evaluated roadblocks to students' ability to connect with the heart of the engineering challenges. While using FLEET educationally, we determined key instructional strategies to move students from a gaming mindset to a STEM, and later a STEAM, mindset. We formalized these approaches in our middle- and high-school curricula that align to states' science and reading standards. The curricula first require students to work collaboratively and establish their own engineering process. Then, students engage with scientific concepts like force and energy before applying that knowledge in FLEET's physics simulator. Finally, students use FLEET in teams to design solutions to naval challenges. These FLEET capstone experiences engage students in 21st Century Skills, like collaboration and creativity, and truly integrate STEAM disciplines. Students sketch and present solutions to complex engineering challenges using a physics simulator. By honing our instructional plan, we modified the video game purposefully to fit this learning environment. Initial data analysis shows positive relationships between the amount of engagement students had with FLEET and their ability to see themselves in STEM professions. Data also shows that students rate their experience with FLEET favorably. More data is being gathered this Fall and Winter to allow for more robust data analysis.

Keywords

Engineering, Education, K-12, Simulation, Video Game

I. Introduction and Literature Review

The Office of Naval Research wanted to give students an authentic engineering experience, so they worked with the American Society of Naval Engineers (ASNE) and Navatek, Ltd. To design the FLEET video game to inspire high-school students' interest in naval engineering. The virtual nature of this approach engages student populations far from the typical reach of naval-engineering outreach programs. It connects under-served students, including those in rural environments, to naval engineering. The video game platform also affords opportunities to create rich engineering problems that encourage students to utilize engineering design processes as well as critical science and math content knowledge. Subsequent development and evaluation cycles focused on deepening this connection between science, technology, engineering, and mathematics (STEM) disciplines while removing barriers that decrease student motivation.

Educational games have long been used to increase student motivation.[1][2] Now, video games are nearly ubiquitous as 90% of teens report playing video games (83% of girls and 97% of boys), and access to a gaming console at home does not vary across income levels.[3] Users of some games, like Kerbal Space Program and Civilizations, report significant increase content area knowledge,[4] Video games allow students to experience many facets of a career and the ways students play them have been correlated with different STEM careers.[5][6] For these reasons, video games have been used to connect careers and video games. For example, Castronova, Zappe, Messner, and Leicht explored how the Virtual Construction Simulator (VCS) allowed college students to explore the Architecture, Engineering, and Construction industry.[7] FLEET's design theory is similar to VCS; if students have an opportunity to engage authentically in a profession, then they may be motivated to consider this career and the STEM pathways that lead to it. FLEET is unique in trying to accomplish these goals with high-school students.

To investigate this design theory, FLEET has been implemented, evaluated and revised since 2016. This implementation includes educational supports like lesson plans, curricula, and reading text sets. The program is regularly evaluated through surveys focused on the gameplay experience and its impact on students' future STEM/naval engineering plans. FLEET is still a work in progress as ASNE and Navatek improve and expand the gaming experience.

Figure 1. Engineering interface showing helicopter options and an over-budget ship.

II. Methods & Implementation

FLEET engages learners in iterative ship design beginning from drydock construction, where students make critical design decisions on layout, powering, and loading (e.g. understanding Archimedes' principle, buoyancy, weight, and balance), followed by sea trials of their vessel to gauge performance of the design and quantitatively assess their vessel. The student experience culminates with missions in which students gain an understanding of applied engineering and consequences of design tradeoffs in an operational environment (e.g. removing a helicopter for weight mitigation may affect search and rescue functions).

The design interface is tailored to each mission and students are reminded of mission requirements by a continuously-updated checklist. For example, in the Search & Rescue mission students can choose from over 20 types of equipment to create over 800,000 possible ships.

Students then adjust the water in their ballast tanks to ensure the ship is stable and designed for high performance. When the ship is ready to test, students move out of the design interface and into the gameplay interface. Student ships are initially subjected to a Stability Test which gives students feedback about the weight distribution on their ships through messages and visual feedback. Then, students could attempt a mission, like the Search & Rescue mission which challenges students to travel about 1.25 nautical miles to a shipwreck and save five sailors in the water while maneuvering around the wreckage and debris. Or, students could test specific aspects of their ship. The Speed Test assesses quickness, Rescue Practice assesses efficient human rescues, and the Maneuverability Test assesses the ship's ability to maneuver. Each test gives feedback on one aspect of the larger missions. This design mirrors engineers' practice of testing isolated variables. And, these tests yield real-time data, like time, velocity and distance traveled, allowing students to calculate measurements like acceleration, force, work, and power. We found that students do not naturally engage in these behaviors unless scaffolded previously, so educational curricula were created to highlight the engineering process, data collection, and physical science vocabulary. This program revision is currently being assessed, but we already have preliminary student survey data about the motivational aspects of the FLEET video game.

The FLEET student survey is a 15-item, post-intervention measure with five demographic questions, two questions about FLEET participation, five Likert-type questions, and three open-ended feedback questions. Demographic items address gender, age, race, ethnicity, and number of STEM programs previously attended. FLEET participation is measured by the number of missions completed (see Table 1) and the number of FLEET events attended. The five Likert-type questions in Table 1 have five response options (Strongly agree, Agree, Undecided, Disagree, Strongly Disagree), which are recorded as a 0-4 score with 4 representing "Strongly agree." The three open-ended questions ask for students' suggestions to improve the video game, the program, and anything else in FLEET. All surveys are completely anonymous and voluntary.

Table 1: Six items focused on FLEET video game use and its impact

Item	Question Stem	Response Type
1	Please indicate which missions you have completed.	Multiple Select
2	Participation in FLEET increased my interest in pursuing a STEM career.	Likert-type
3	Participation in FLEET increased my interest in pursuing a naval engineering career.	Likert-type
4	The FLEET software was easy to navigate.	Likert-type
5	I would recommend FLEET to a friend.	Likert-type
6	Overall, I am satisfied with my decision to participate in FLEET.	Likert-type

III. Preliminary Results

FLEET data was gathered between May 2017 and June 2018 from 46 students. There were more boys (N = 37) than girls (N = 8; one student preferred not to identify gender). The sample includes three Asian-American, 20 African-American, 14 White, and three Multi-Race students (four students preferred not to identify race). Seven students identified as Latino/Latina, 33 students did not identify as Latino/Latina, and six preferred not to identify. Students completed slightly more than one mission on average (M = 1.37, SD = 0.84). The student subgroups were too small to yield significant statistical relationships. Item 6 data showed students agreed most

strongly that they were satisfied with their decision to participate in FLEET (M = 3.24; SD = 0.71). They agreed least with item #3 which addressed whether FLEET increased their interest in becoming a naval engineer (M = 2.30, SD = 0.96). The latter was important because increasing students interest in becoming a naval engineer is a primary goal of the program. In this student sample, 11% strongly agreed and 28% agreed that FLEET increased their interest in becoming a naval engineer, while 46% were still undecided, 11% disagreed, and 4% strongly disagreed.

Initial data analyses show correlations between responses to some of the Likert-type data, but we found no correlation between the number of missions played and perceptions about FLEET or STEM careers. The strongest correlations were for items that focused on similar topics, like #5 and #6 (r = 0.77, p <0.01) as well as #2 and #3 (r = 0.66, p <0.01). Although the lowest Likert-type responses were for Item 2, agreement with the statement that FLEET increased personal interest in becoming a naval engineer significantly correlated with finding the software easier to use and satisfaction with participation in FLEET.

The number of missions completed, Item 1, is a proxy for amount of FLEET played. The number of missions completed did not significantly correlate with responses to the Likert-type questions. This finding suggests that more exposure to FLEET would not lead to greater interest in STEM careers or becoming a naval engineer. It is also plausible that Item 1 is a poor measure of the amount of FLEET played or may indicate that this sample is not large enough to ascertain a possible relationship. In a similar vein, we found no significant relationships between the number of STEM programs a student engaged in previously or the number of live FLEET events attended and their experiences in FLEET. However, the qualitative feedback was valuable.

Student feedback to the open-ended items ranged from appreciation (e.g., “outstanding) to specific suggestions for better gameplay. For example, six students suggested improving the graphics (e.g., “Better graphics - more textures”), four students suggested changes to the ballast-tank interface (e.g., “More ease when filling the ballast tanks”), and three students requested more missions (e.g., “possibly more missions”). No other theme appeared more than once. Developers regularly incorporated this feedback into their revisions. The ballast-tank interface improvements were already released, and new missions are released on schedule.

IV. Conclusions and Future Work

Students enjoy FLEET and many students indicated that FLEET gameplay is increasing their interest in STEM careers, specifically naval engineering. Future evaluations with larger student samples will examine whether the observed trends are replicated and whether new relationships emerge. New studies will need to examine whether students using FLEET and/or the FLEET curriculum have a significant increase in scientific knowledge. These data will also reflect the improved video game and educational supports. This future work continues to evaluate the design, development and implementation of FLEET and its learning supports so students can better explore naval engineering and its STEM foundations.

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