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Using Gamification and Aquaponics to Enhance STEM Engagement and Sustainability Awareness

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With a passion for informal STEM education and citizen science, Linda is dedicated to inspiring future engineers through engaging, hands-on learning experiences. Her research interests span aquacultural wastewater treatment, spatial visualization, and STEM outreach. She also actively promotes STEM outreach initiatives to foster inclusivity and innovation in engineering.

Using Gamification and Aquaponics to Enhance First-Year Engineering Engagement

Abstract

This study investigates the impact of gamification on student engagement and interest within a STEM context, specifically focusing on first-year engineering students (n=14). Participants were divided into two groups: one receiving a traditional 15-minute lecture on aquaponics and sustainability, and the other participating in a gamified challenge involving team-based aquaponics-themed system design. While the project also included a brief investigation into the effects of salinity on lettuce growth, the primary focus was to determine if gamified challenges improve engagement compared to traditional lectures. Results indicated that the gamified cohort reported higher engagement and interest in unfamiliar topics like Biological and Agricultural Engineering (BAE), supporting the integration of competitive, team-based activities into STEM pedagogy.

Introduction

Engaging first-year engineering students in science is essential for solving global challenges. As students transition into higher education, activating their scientific understanding is critical for informed decision-making. Traditional methods often struggle to maintain high engagement levels, particularly with specialized engineering disciplines and unfamiliar topics [1]. To address this, the study explores gamification, the use of game-design elements in non-game contexts, to increase content engagement and retention. The research question asks: Does gamifying aquaponics content with team-based challenges improve student engagement compared to traditional lectures?

Literature Review

Gamification is gaining traction in science education as a method to increase concept retention and engagement in large engineering courses [2]. Many gamification studies have been made in the past several years in first year engineering programs in North American and abroad [3], [4]. Most recent of these have involved complex redesigns of large courses [3], [4], [5]. Some based their gamified content on existing board or card games like Battleship and Taboo [3], [6], student-led escape game development [7], and role-playing games [8]. Retrofitting or redesigning large courses with gamification is challenging for instructors of large classes to prepare for complicated gamification schemes [9]. Despite the drawbacks of using gamification in upper level classes like Material Science and Statics, game modifications have been shown to increase motivation to achieve material mastery and reduce student stress levels over course grades in technical classes [4], [10].

The use of game-enhanced experiential learning is common in general STEM, but using it specifically to introduce specialized disciplines BAE via timed challenges is a niche that hasn't been fully explored. Research indicates that students studying science may experience greater benefits from gamified content than those in non-science fields. Gamification encourages participation in academic activities, helping students utilize abstract thinking to understand complex concepts more deeply. Aquaponics, which combines aquaculture and hydroponics, serves as a vehicle for such activities, offering insights into sustainability, water science, and systems thinking. Recent studies suggest that hands-on, project-based learning in aquaponics builds student confidence [11] and problem-solving skills [12].

While current literature extensively documents the use of aquaponics in K-12 engineering education [11], there is a notable gap in the research regarding its application as a recruitment and engagement tool for first-year engineering students. Additionally, gamification has shown promise in general STEM settings [12], the specific use to introduce students to specialized disciplines like BAE through timed design challenges remains under-examined.

Methodology

The study involved 14 Engineering First-Year (EFY) students split into two cohorts detailed below. Students were recruited from a first-year introductory engineering course to participate in high-impact activities (HIAs) designed to help them choose an engineering discipline into which they might consider exploring further prior to officially matriculating. One of the requirements of the intro course is to attend at least two HIAs during the semester. Failure to do so adversely affects their final grade. They record their attendance and write a short reflection for their respective instructors. The motivation to conduct this project was to include a BAE-focused HIA for major exploration. BAE is typically not considered as a first-choice major. There are 18 engineering disciplines to choose from.

- Group A (Traditional): Received a 15-minute lecture on aquaponics and food insecurity, followed by a brief hands-on taste test of lab-grown lettuce and a lab tour.
- Group B (Gamified): Participated in a 15-minute gamified session using the same content, followed by a lab tour with Group A.

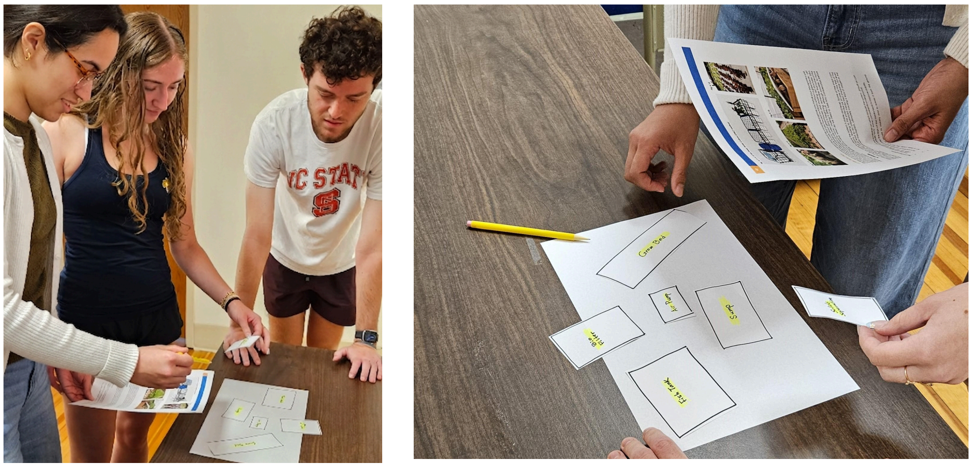
After a short introduction, all participants (n=7) were given a pre-survey (See Appendix). After the survey, they were split into groups. Group A with the author in one room to experience the traditional lecture. Group B was taken to an adjoining room to experience the gamified version of the lecture material. A mockup of the activity sheet for the game is available in the Appendix. After 15 minutes, the groups reconvened and took the post-survey (See Appendix). Both surveys were administered via Google Sheets. No identifying information was collected. The raw data was analyzed only by the author.

The Gamification Model

The seven students of Group B were split into three teams (one team of three and two teams of two each). The teams were given the option to pick a name based on one of the following aquatic species: tilapia, oyster, sturgeon, lettuce. After a brief introduction covering some basic information about aquaponics, climate change, and food security, they were tasked with designing an aquaponics system using general paper cutouts for their assigned species to thrive in

(Figure 1). Their design had to include details about size, nutrient components, water quantity and flowrates, and economics. Participants were allowed to consult the internet for information. Curated the university's Cooperative Extension Service web-based resources were provided via QR codes. Each team had 15 minutes to complete the design challenge.

Figure 1. Example of Group B gamified activity



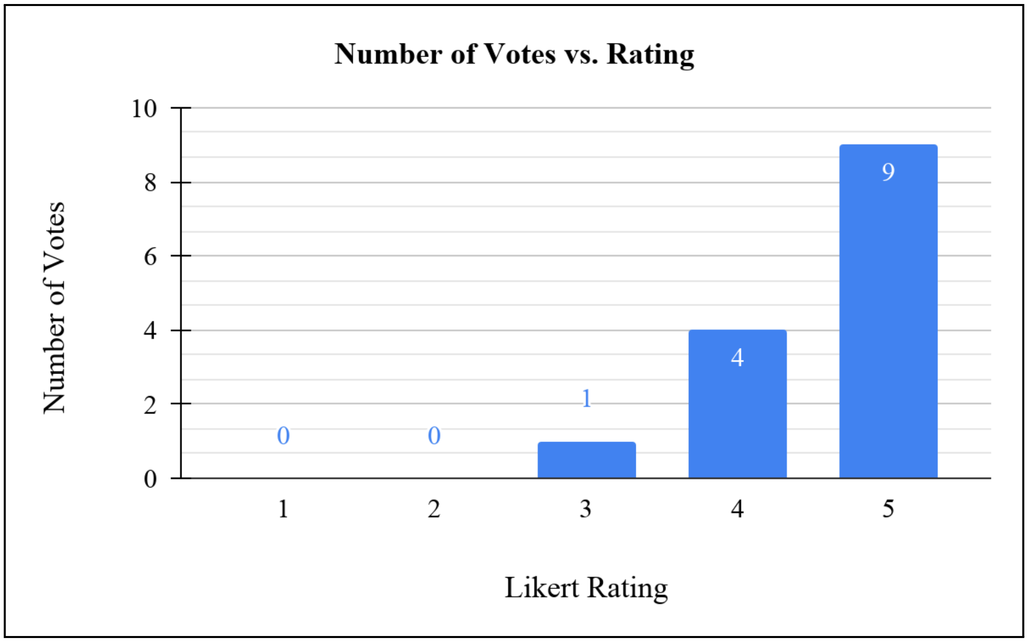
Supplemental Hands-on Components

To provide context, students participated in a brief taste test of lettuce grown under varying salinity levels in a laboratory setting. This lettuce was cultivated using the Kratky (passive hydroponics) method, where higher salinity (up to 10 ppt) was used to demonstrate its inhibitory effects on plant growth. While salinity and sustainability were part of the lesson, these elements primarily served as the thematic backdrop for the gamified challenge.

Results

The primary objective of this study was to evaluate the efficacy of gamification versus traditional lecture in fostering student engagement with unfamiliar engineering topics. While 9 out of 14 total participants rated the experience highly, the majority of these top-tier ratings originated from Group B (the gamified cohort) (Table 1). What's more, participants in the gamified group reported higher levels of interest in unfamiliar disciplines, specifically BAE, compared to the traditional lecture group. Students in the gamified cohort explicitly noted that the challenge was "much more engaging than just a lecture". Participants described the activity as "a lot of fun" and expressed a desire to "learn more about [BAE]". Feedback indicated that the 15-minute gamified unit helped students identify overlaps between their intended majors and biological systems, broadening their career awareness.

Table 1. Likert ratings showing higher ratings for 9 of 14 participants



Discussion

The primary takeaway is that gamification, especially when combined with hands-on experiences, effectively increases interest in specialized fields like BAE. Students in Group B reported that the competitive, team-based design challenge made the content “a lot of fun” and helped them see the overlap between their majors and biological systems.

This project demonstrates that even short, 15-minute gamified units can broaden career awareness and challenge student assumptions about certain engineering disciplines. While the sample size was small (n=14), the qualitative data strongly suggests that the timed, collaborative nature of the challenge fostered higher levels of enjoyment and engagement than the traditional lecture format.

Conclusions

The results of this study suggest that even a brief, 15-minute gamified intervention can significantly impact student perception of specialized STEM fields. By shifting from a passive lecture to an active, competitive design challenge, students were forced to apply abstract concepts, such as flow rates and nutrient components, to a tangible engineering problem.

Participants in Group B reported that the timed, team-based nature of the aquaponics challenge made the content “a lot of fun”. This suggests that the social and competitive elements of gamification help lower the barrier to entry for complex, unfamiliar disciplines like BAE. While the traditional lecture group received the same core information, they lacked the hands-on requirement to immediately process and utilize that data.

A critical takeaway for first-year engineering educators is the role of gamification in career awareness. Many students enter engineering with narrow definitions of the field, however, this activity helped Group B see the direct overlap between their intended majors and biological systems. By utilizing aquaponics as a vehicle for systems thinking, the study successfully activated scientific understanding in a way that traditional methods often struggle to achieve.

It is important to acknowledge the small sample size (n=14). While the qualitative feedback is strongly in favor of gamification, these results are preliminary. Future iterations will need to explore whether this engagement spike leads to long-term interest or actual matriculation into specialized engineering departments.

Appendix

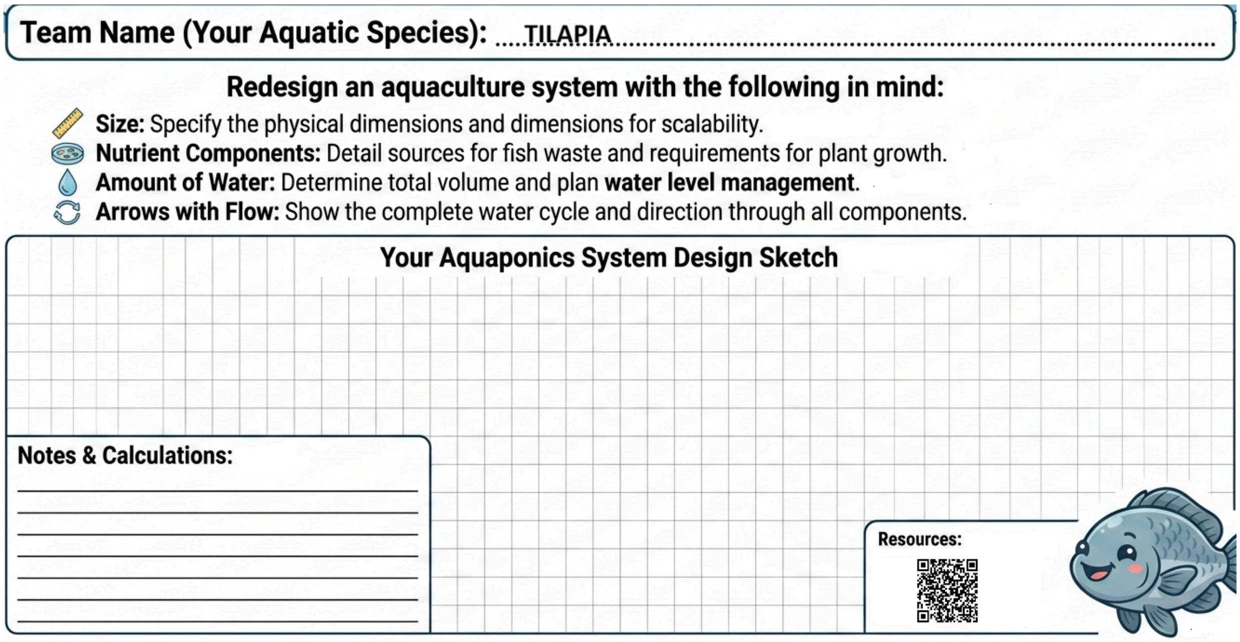
Pre-survey for all participants

Question	Options
Have you ever heard of aquaponics before?	Yes No
What do you think are the benefits of growing food using aquaponics?	[Short answer format]
What types of plants and animals do you think can be part of an aquaponics system?	[Short answer format]
On a scale of 1–5, how interested are you in learning about how food is grown?	[5-point Likert scale format]
What do you think makes water quality important for growing plants and raising fish?	[Short answer format]

Post-survey for all participants

Question	Options
How would you explain aquaponics to a friend or family member?	[Long answer format]
What was the most interesting thing you learned during the quest?	[Long answer format]
What surprised you the most about aquaponics?	[Long answer format]
How would you rate the hands-on activities and/or taste test?	[5-point Likert scale format]
Would you be interested in learning more about aquaponics or doing a similar activity in the future? (Yes/No, explain why)	[Long answer format]
What is one question you still have about aquaponics?	[Long answer format]

Mockup Activity Sheet for the Aquaponics “Game”



Team Name (Your Aquatic Species): TILAPIA

Redesign an aquaculture system with the following in mind:

- **Size:** Specify the physical dimensions and dimensions for scalability.
- **Nutrient Components:** Detail sources for fish waste and requirements for plant growth.
- **Amount of Water:** Determine total volume and plan **water level management**.
- **Arrows with Flow:** Show the complete water cycle and direction through all components.

Your Aquaponics System Design Sketch

Notes & Calculations:

Resources:

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