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The Effectiveness of Game-Based Flipped Learning on Academic Achievement and Engagement

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The Effectiveness of Game-Based Flipped Learning on Academic Achievement and Engagement

Abstract

Abstract

This study aimed to determine if a game-based flipped learning (GBFL) environment was an effective learning model relative to flipped learning alone. Three sections of 6th-grade science students received varied methods of instruction by the same teacher over four weeks. One section received traditional, face-to-face instruction, another section worked in a flipped learning (FL) environment, and the last section worked in a proposed GBFL environment. A standardized pretest and posttest alongside a mixed-method student survey were administered to determine the effectiveness of each strategy in terms of academic achievement, student engagement, and satisfaction. The study's results indicated that GBFL resulted in similar academic improvements yet greater student satisfaction than the other two groups. ANOVA and Pearson Product Moment Analyses indicated that each learning method resulted in substantial academic improvement with slight variance between groups ($p=0.07$). A moderate positive correlation existed between posttest scores and student satisfaction in the GBFL group ($r=0.314$). These results indicate the potential of GBFL as a learning model and the future research required for validation.

Keywords

Gamified learning, Flipped Learning, Game based learning, game, educational games, instructional games

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The Effectiveness of Game-Based Flipped Learning on Academic Achievement and Engagement

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Introduction

Harold "Doc" Edgerton, the late MIT professor and father of high-speed photography, once shared his motto for education: "The trick to education is to not let them know they are learning something until it is too late" (Oram, 2023). In other words, learning will be inevitable if teachers create environments where students are enthralled by their tasks. "Doc" Edgerton's outlook on education continues to bloom as technology advances. Technology has opened doors to environments where students direct their learning instead of teachers. One of these newly opened doors is known as flipped learning (FL). In the FL environment, students direct their learning by engaging with materials facilitated by the instructor on their own time, outside the classroom (Brame, 2013).

Once the students have familiarized themselves with the material, they are then ready to enter the classroom to engage in higher-order thinking activities with their peers such as group projects and creative problem solving. Research has demonstrated the effectiveness of FL academically and in terms of student and teacher satisfaction (Fung et al., 2021). Teacher-directed learning environments have stood as the primary and most effective means of education (Ajmal & Hafeez, 2021). However, the gap in academic effectiveness and satisfaction between traditional classrooms and FL classrooms is closing more and more each year (Wright & Park, 2021). Another educational avenue that has opened thanks to emerging technology is game-based learning (GBL) environments. In GBL environments, students utilize games to support instruction and skill development (Erhel & Jamet, 2013). Similarly to FL, GBL environments have shown similar promise in academic achievement, satisfaction, and even attendance (Subhash & Cudney, 2018).

The similar benefits observed in FL and GBL beg the question: Can students experience additive benefits of FL when combined with GBL? The research behind this combination, game-based flipped learning (GBFL), in K-12 settings is only just emerging. This study aims to contribute to the small but growing body of research behind GBFL. To meet this goal, I submit the following hypothesis:

Hypothesis: A GBFL environment will improve 6th-grade science students' academic outcomes and engagement with science content relative to traditional and FL environments.

Literature Review

Conception of Flipped Learning

FL conceptually emerged in academic literature in 1993 with Alison King's work *From Sage on the Stage to Guide on the Side*. In her article, she argued that most universities practice a "transmittal model" of education, where a teacher transmits knowledge to passive students. In response, she argued that these students should be engaged in constructivist practices to transition from passive to active learners (Ağırman & Ercoşkun, 2022).

Based on this work, three university professors went one step further with the emergence of the "inverted classroom" in 2000. Maureen J. Lage, Glenn J. Platt, and Michael Treglia at the University of Miami developed the inverted classroom out of necessity as they did not have enough classroom time throughout the semester to convey all the required microeconomics content to their students (Lage et al., 2000). In their work, they asserted that to meet the needs of every student, the amount of class time offered would need to increase fourfold. Instead, the researchers leveraged emerging technology by requiring students to listen to lecture recordings and interact with PowerPoints created by the instructors outside of class. Their strategy was successful and generally well received (Lage et al., 2000).

The term "flipped classroom" emerged in earnest in 2012 with Jonathan Bergmann and Aaron Sams's book entitled *Flip Your Classroom: Reach Every Student in Every Class Every Day.* In their work, they noted the advantages of FL and afforded lower achieving students opportunities to pause video instruction to repeatedly engage with the material (Bergmann et al., 2012). It was from this work that FL research exploded. According to a meta-analysis by Dr. Robert Talbert, research concerning FL has grown exponentially. Only two articles on FL had been published in 2000; one being the work of Lage, Platt, and Treglia. By 2015, 146 FL articles were published, and by 2021, 1,383 research articles had been published (Talbert, 2022).

Despite growing popularity amongst educators, FL remains in its infancy. Though FLis generally rooted in constructivist theory, many studies fail to adhere to accepted learning theory (Talbert, 2022). One study of secondary teachers in Spain found that less than half, 758 out of 1,743 teachers, demonstrated competency in developing a FL classroom based on accepted constructivist theory (Moreno-Guerrero et al., 2021). Though the best practices of FL remain in flux, several fundamental learning theories and strategies have been consistently tried and found effective.

Flipped Learning Pedagogy

Successful FL environments often display recurring themes regardless of grade level. Since the publication of Jonathan Bergmann and Aaron Sams's work *Flip Your Classroom: Reach Every Student in Every Class Everyday* in 2012, a few pillars of successful FL have emerged. FL environments based on constructivist learning theory promote technology integration and emphasize individualized instruction, typically resulting in higher student achievement and engagement (Richey et al., 2010).

Constructivist learning theory posits that learners create their understanding through opportunities to reflect on the learning process (Spiro et al., 1991). In practice, constructivism is on display when students engage in new experiences through higher-order thinking activities alongside their peers (Richey et al., 2010). Higher-order thinking activities can include group activities, hands-on exercises, and creative demonstrations of knowledge. Constructivist instructors typically act as facilitators of knowledge as opposed to transmitters. As Alison King asserted, constructivist educators are not “sages on the stage; rather, they are guides on the side” (Ağırman & Ercoşkun, 2022). FL environments encourage rigorous learning based on contextual, real-world issues. Project-based and problem-based learning are frequently utilized to inspire student inquiry, autonomy, and problem-solving skills. FL also affords the constructivist principle of cooperative learning (Richey et al., 2010). Students study independently outside of class and are more likely to wrestle with project-based activities with partners and in groups (Strayer, 2012). These cooperative learning opportunities allow students to fill gaps in understanding and “construct” what information they deem most valuable.

FL can also be highly advantageous for individualizing instruction. High-achieving, intrinsically motivated students can accelerate while emerging learners can receive the additional attention they need in the classroom (Kim et al., 2014). Students who have already labored through the initial learning content are more likely to receive additional feedback than students in traditional classrooms (Kesharwani & Kesharwani, 2022).

Though FL may come with many opportunities, a few drawbacks remain. Student motivation and academic fidelity outside the classroom remain the largest obstacles for FL students (Jong, 2022). Regardless of the grade level, students can struggle to transition from passive to active learning (Ağırman & Ercoşkun, 2022).

Emergence of Game-Based Learning

Jean Piaget’s work in the 1960s laid the research foundation for learning through play. Piaget described play as integral to a child’s development (Plass et al., 2015). Though play is widely acknowledged as a fundamental tool for learning, academia still has a hard time pinning down the definition of a “game.” For our purposes we will define a game as “a physical or mental competition conducted according to rules with the participants in direct opposition to each other” (Merriam-Webster, 2019). Game-based learning (GBL), in contrast, are situations in which these competitions are leveraged for learning opportunities.

Academic scholars generally agree that GBL rests on least three pillars of success: motivation, player engagement, and adaptability. These pillars are used in game design and result from combinations of behaviorist, cognitivist, and constructivist principles (Lenhart et al., 2008). Regarding player motivation, Eccles, Wigfield, and Schiefele assert that the learner will often ask three questions: 1.) Can I do this? 2.) Do I want to do this, and why? 3.) What do I need to do in order to succeed? (Eccles et al., 1998). In other words, a motivating educational game is one that inherently motivates students to learn by providing in-game experiences that are enjoyable and satisfying. Player engagement also serves as a key motivator. Learners engaged in a competitive learning game will likely improve collaboration, communication, problem-solving, and socio-emotional skills (Denning et al., 2011). Finally, adaptability within a GBL environment can foster several skills within the player. Some educational games are adaptable because they do not have specific learning objectives; instead, they provide experiences that can be called upon for future learning (Plass, Perlin et al., 2010). These games allow students to interact with new information while reinforcing existing knowledge with the hopes of learning automation. GBL may contribute to the emotional maturation of students by evoking teamwork, problem-solving, and regular communication (Plass, Perlin et al., 2010). When all three pillars of gaming are in sync, the students can experience transformative learning. These benefits may be one reason why educational games, particularly computer-based games, are growing in prevalence.

According to Pew Internet & American Life Project, 97% of children, ages 12-17, play online video games; 99% of boys and 94% of girls are actively involved with video games (Lenhart et al., 2008). This overwhelming participation of youth in online gaming has immense potential to be leveraged in education. Online games in classrooms are here to stay. A 2013 Games and Learning Publishing Council study surveyed 694 K-8 teachers and found that 74% were using digital games for instructional purposes (Takeuchi & Vaala, 2014). The percentage of teachers and students who utilize online educational games continues to rise alongside those who are engaged in flipped classrooms. This fact has led some researchers to ask: Can GBL solve common motivational problems within FL classrooms?

Game-Based Flipped Learning in Science Classrooms

GBFL research is scant, however, some promise has been found at the collegiate level. GBFL environments, in which stimulating digital games are offered, develop students' critical thinking abilities, raise academic achievement, and improve fidelity in coursework in comparison to FL alone (Hwang & Chang, 2020). When the appropriate game(s) are chosen and proper support is provided, GBFL has been shown to be more fulfilling and useful than quizzes of equivalent rigor (Dermentzi, 2023). In science classrooms, GBFL can have a sizable effect on learning outcomes. When educators provide sufficient support in tandem with selecting games with engaging mechanics, students' acquisition of science knowledge significantly improves (Tsai & Tsai, 2020).

To determine the effectiveness of GBFL at the middle school level, we explored the following problem:

> *Problem(s):* Research regarding the academic effectiveness of FL is limited at the middle school level and GBFL is almost non-existent.
> *Objective:* Increase student academic achievement and engagement by offering an alternative mode of FL.
> *Hypothesis:* A GBFL environment will improve 6th-grade science students' academic outcomes and engagement with science content relative to a traditional and FL environment.

Methodology

Participants

This study aimed to determine the academic and motivational effectiveness of GBFL in the sixth-grade science setting. To do so, we examined the academic and motivational learning outcomes across three different instructional means: 1.) a traditional, lecture-based classroom, 2.) a FL classroom, and 3.) a GBFL variant.

This study adopted a blended positivist/interpretivist approach using deductive reasoning in collecting quantitative and qualitative data to determine the potential benefits of GBFL. A pretest and posttest were used to assess each classroom's academic effectiveness quantitatively. A mixed-method survey at the study's end provided insights into student engagement and satisfaction with each classroom. This comprehensive methodology ensured a thorough evaluation of the academic and motivational effectiveness of the proposed GBFL model.
The three experimental groups in this study were the sixth-grade science students at Lyons Middle School in Lyons, Kansas. Lyons is in a rural, agricultural community with a population of approximately 3,500. The researcher was the sole science teacher for all 46 sixth-grade students. This group of 46 students was divided into three sections: GBFL, FL, and traditional learning, containing 14, 16, and 16 students, respectively. These students ranged from 11-12 years old and were 49% female to 51% male. 51% of students acknowledged themselves as Caucasian, 42% as Hispanic, and 7% as multiracial. 16% of the sixth-grade students were English language learners (ELL), with 3% being migrant students, all of whom spoke Spanish as their first language. Each ELL student had access to a paraeducator for translation assistance. 24% of the sixth-grade students had a documented health deficiency or an Individualized Learning Plan (IEP) with paraeducator assistance. 80% of our sixth graders had been classified as economically disadvantaged and received free or reduced lunch. The students in this study had very limited to no background knowledge of the covered science standards. Each participant in this study was considered vulnerable due to their age. As a result, each student's guardian received a consent form before participating in the study. This consent form acknowledged that no private or identifying information about their student was ever shared. Only aggregated data was collected for this study; however, guardians reserved the right to withdraw from the study at any time.

Instruments/Materials

This study primarily took place in the traditional classroom, however, some parts of the study required students to complete activities outside of school. Each student had a Dell laptop and internet access while at school. Students who did not have secure internet access at home had the opportunity to stay after school to complete the required activities. Internet resources used throughout the study included Stemscopes, EdPuzzle, Gimkit, and Blooket. Stemscopes was the primary science curriculum and offered many online resources for students and teachers. Stemscopes is an emerging online science curriculum adopted by K-12 schools throughout the United States. It has been shown to be an effective means for students to achieve mastery of NGSS science standards (Cook et al., 2023). Stemscopes has also been shown to generate high achievement in standardized tests amongst ELL students (Rangel et al., 2013). Students accessed online assignments, videos, simulators, and learning materials in school and at home using Stemscopes. EdPuzzle is an interactive video service that allows students to answer formative comprehension questions through a teacher-selected video. This site allows teachers to assign videos for students to watch, automatically pauses the students' video, and provides a comprehension question with each pause. Students could not fast-forward the videos or skip any questions to ensure fidelity with the assignment. Gimkit is an educational gaming website that promotes student engagement by providing memorable educational gaming experiences. Educators may create quizzes within Gimkit and allow students to choose from a suite of games to study the created material. The student may play these games individually or collectively as a class. Students may also “buy” upgrades and perks using points earned within the game and see leaderboards as an added motivational incentive. Blooket is another educational gaming site that functions similarly to Gimkit. Blooket contains different gaming options but offers the same benefits to teachers and students. Student scores within the games directly correlate with in-class prizes. These prizes include: “Get Out of Homework Free Passes”, stickers, fidget toys, and “Lion Pride Bucks” which may be used to enter drawings for larger prizes. In this regard, students were intrinsically and extrinsically motivated to rigorously engage with the educational games.

Procedure

The study focused on the effects of different learning environments when covering the same material. Each section received 200 minutes of varying instruction each week over four weeks. During this time, students learned about Newton’s Third Law of Motion following the middle school Next Generation Science Standards (NGSS). These NGSS learning standards read as follows:

- MS-PS2-1: Apply Newton’s third law to design a solution to a problem involving the motion of two colliding objects.
- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, considering relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

On the first day of the study, all students completed a 20-question, multiple-choice pretest on paper over the chosen NGSS standards. The questions had been curated by Stemscopes to address the disciplinary core ideas, cause and effect concepts, and comprehension of Newton’s Third Law. The same paper test was given at the end of the study to determine the relative academic growth of each group. An example question from the assessment is as follows:

> *A baseball bat hits a baseball with a force of 100 Newtons. What is the force and direction the ball exerts on the bat?*
>
> **A** *100 Newtons, same direction*
> **B** *100 Newtons, opposite direction*
> **C** *200 Newtons, same direction*
> **D** *200 Newtons, opposite direction*

The students in the traditional learning group served as our control group. These students received in-school instruction within the 200 minutes of weekly class time. The teacher instructed primarily through lecture and notetaking supplemented with some constructivist-based activities such as group and project work. The first comparison group was the FL environment. Students in this group received initial instruction outside of class using teacher-curated videos and lectures accessed online through Stemscopes and EdPuzzle. Once the materials were completed outside of class, students used their class time to reinforce what they learned using group work and project-based inquiry. The GBFL group followed the same procedures as the FL group. However, instead of utilizing Stemscopes and EdPuzzle to drive instruction outside of class, they used the gaming platforms Gimkit and Blooket. Within the classroom, they were engaged in constructivist-based instruction, higher-order thinking tasks, and additional Gimkit and Blooket gaming opportunities. Students completed their 20-question posttest after four weeks of study.

Additionally, students participate in a mixed-method survey at the beginning and end of the four weeks. The survey utilized three open-ended and three 5-point Likert scale questions to determine engagement and satisfaction with each learning style. The student engagement survey included the following questions:

Open-ended questions:

1. Question #1: What do you feel is the best/easiest part about how we learned in this unit?
2. Question #2: What was the most challenging part of learning throughout this unit?
3. Question #3: What would have made learning this unit easier for you? (What would you have done differently if you were the teacher?)

Likert-Scale Questions:

4. The way we have been learning Newton's Third Law is interesting.
    - Greatly Agree
    - Agree
    - Not Sure
    - Disagree
    - Greatly Disagree
5. The work outside of class helped me understand Newton's Third Law.
    - Greatly Agree
    - Agree
    - Not Sure
    - Disagree
    - Greatly Disagree
6. I would like to continue learning in science class this way.
    - Greatly Agree
    - Agree
    - Not Sure
    - Disagree
    - Greatly Disagree

Results

Academic Achievement

Table 1 shows the results of each group's pretest, posttest, and level of improvement. Based on the average test scores, students scored similarly on both the pretest and posttest. However, the traditional learning group showed the greatest improvement, nearly 4% over all the groups. Table 2 shows a one-way ANOVA test comparing the relative means of each learning group. These analyses indicate that no significant difference emerged academically between the three groups (p = 0.07).

Table 1. Average test scores of each learning model

	Pretest	Post	Differrence (%)
GBFL	49.09%	84.29%	35.19%
Flipped	54.40%	90.00%	35.60%
Traditional	45.33%	84.75%	39.42%
Avg.	49.61%	86.35%	36.74%

Table 2. ANOVA comparison of academic improvement of each group

Anova: Single Factor	Pre/Post Test Difference					
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
GBFL	13	4.598	0.353692308	0.04748473		
F.L	14	4.964	0.354571429	0.04836657		
Traditional	14	7.209	0.514928571	0.03126069		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.238332776	2	0.119166388	2.82143565	0.07203364	3.244818361
Within Groups	1.604971126	38	0.042236082			
Total	1.843303902	40				

Student Satisfaction

Student satisfaction levels were codified from the 5-point Likert scale; “5” represented “Greatly Agree,” and “1” represented “Greatly Disagree.” The open-ended questioning revealed no impactful, codifiable data, as student responses were sporadic. However, Table 3 shows the average score of each Likert-scale question students answered following the post-test. Students in the GBFL group consistently scored higher on average in each category. The FL group nearly aligned with the average of each score, while the traditional learning group consistently scored below average in each category.

Table 3. Average Likert-scale scores of each learning model

	Understood Material	Interest Level	Continue Learning this way
GBFL	4.00	4.00	4.54
Flipped	3.94	3.63	4.13
Traditional	3.87	3.47	3.73
Avg.	3.93	3.70	4.13

Table 4 outlines a one-way ANOVA analysis of each group’s response to the prompt: “I would like to continue learning this way in science class.” The GBFL group scored nearly an entire point higher than the traditional learning group. This table outlines the most statistically relevant portion of the survey data. However, these data were not statistically significant despite the relatively wide discrepancy in student preferences (p=0.14).

Table 4. ANOVA comparison of each group's willingness to continue their respective learning method

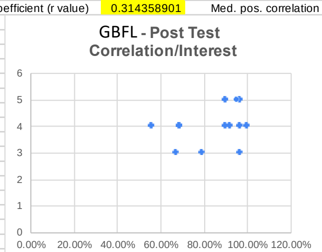
Anova: Single Factor	I would like to continue learning this way in science class.					
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
GBFL	13	59	4.53846154	0.6025641		
F.L.	16	66	4.125	0.65		
Traditional	15	56	3.73333333	2.06666667		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.51771562	2	2.25885781	2.01709638	0.14603274	3.22568384
Within Groups	45.9141026	41	1.11985616			
Total	50.4318182	43				

Academic Achievement vs. Interest Level

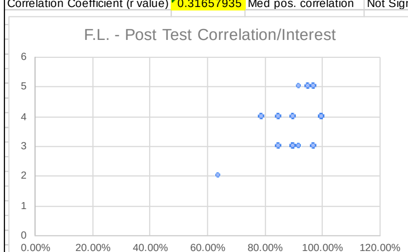
Finally, the student post-test data was compared with students' self-reported interest levels in Person Product Moment tests in Table 5. Based on these data, there appears to be a nearly identical, positive correlation between post-test results and interest level in both GBFL and the FL models (0.314 and 0.316, respectively). A very slight negative correlation existed in the traditional learning group. There appeared to be some connection between interest and student academic outcomes.

Table 5. Pearson Correlation Coefficient of each learning model (Post Test vs. Interest)

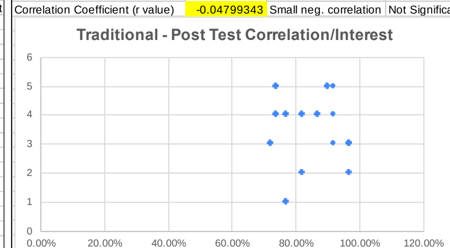
GBFL - Post Test Correlation/Interest			
	Post Test	Interest	
	56.00%	4	
	90.00%	4	
	90.00%	5	
	97.00%	4	
	79.00%	3	
	100.00%	4	
	92.00%	4	
	97.00%	3	
	69.00%	4	
	69.00%	4	
	97.00%	5	
	67.00%	3	
	95.00%	5	
Corr. Coefficient (r value)	0.314358901	Med. pos. correlation	



F.L. - Post Test Correlation/Interest			
	Post Test	Interest	
	85.00%	3	
	85.00%	4	
	92.00%	3	
	92.00%	3	
	90.00%	3	
	97.00%	3	
	97.00%	5	
	92.00%	3	
	95.00%	5	
	92.00%	5	
	90.00%	4	
	90.00%	3	
	100.00%	4	
	64.00%	2	
	100.00%	4	
	79.00%	4	
Correlation Coefficient (r value)	0.31657935	Med pos. correlation	Not Significant



Traditional - Post Test Correlation/Interest			
	Post Test	Interest	
	90.00%	5	
	77.00%	1	
	92.00%	3	
	77.00%	4	
	82.00%	4	
	82.00%	2	
	72.00%	3	
	92.00%	4	
	87.00%	4	
	97.00%	3	
	97.00%	3	
	97.00%	2	
	74.00%	4	
	92.00%	5	
	74.00%	5	
Correlation Coefficient (r value)	-0.04799343	Small neg. correlation	Not Significant



Discussion

Existing literature indicates that GBL environments can positively affect student learning and engagement. Similarly, FL can be an effective instructional method based on constructivist

principles. However, there needs to be more evidence of the cumulative effects of a GBFL classroom, which is almost nonexistent at the sixth-grade level. This study served to fill a substantial gap in the literature regarding middle school, GBFL environments.
This study contained limitations worth mentioning. First, it cast a relatively small net by only investigating 46 sixth-grade students in a rural Kansas setting. Additionally, these students may have been influenced by their demographic or socioeconomic status. Approximately 80% of the students were economically disadvantaged, 16% were English language learners, and 24% required some individualized paraeducator support; this distinctive population may have influenced the results. The students' mood at the time of the mixed-methods survey may have also skewed the accuracy of the self-reporting.

Gauging student interest over the topic as well as game-based learning in the initial questionnaire may have helped determine the effectiveness of each learning strategy. Finally, technology may have been a limitation of this study, as the two groups heavily relied on technology for success. Students' home internet connection and computer performance may have unknowingly affected the results of the FL and GBFL groups. Greater care should be taken to ensure that students have the necessary tools to be successful (i.e. hotspots, time on task outside of school, etc). Students with additional responsibilities outside of school should be considered in greater detail; future studies should track the data regarding out-of-school distractions. It is also worth noting the potential for unintentional reinforcement of student misconceptions due to video-based instruction (Muller et al., 2008).

Conclusions

The data indicates that this iteration of GBFL may be a sound instructional strategy. Though the analyses did not reveal any statistically significant evidence, several patterns emerged that may encourage new iterations of this study. Each group saw similar academic achievement, but the GBFL group displayed considerable student preference. The positive correlation between academic achievement and student satisfaction in the GBFL group suggests future inquiry. Future studies should consider replicating this strategy with larger sample sizes, different populations, and new iterations of the learning model to explore this new territory. Students' home internet status and additional responsibilities outside of school should be considered in greater detail; future studies should track the data regarding out-of-school distractions. Future studies should also detail the preparation of students in strategies for effective self-reporting during the survey. Additional questions in the survey regarding prior interest level in technology, home internet connection, and the opportunity to succeed may shed more light on future research. Another point of interest for future research would be to determine GBFL's effect on project based, engineering practices as stated by the NGSS Engineering standards. Greater attention could be given to the Crosscutting Concepts and Engineering practices when designing the assessments. Maintaining academic rigor while maintaining student engagement is a tricky tightrope to walk. However, cultural and educational shifts indicate a future of gaming, autonomy, and flexibility. GBFL continues to be sculpted as new technology emerges, and our understanding of FL deepens.

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