Are You Game?

Assessing Students' Perception of Learning, Instructors' Perspective, and Learning Attitude

Hadi Hosseini
Rochester Institute of Technology
Rochester, NY, USA
hhvcs@rit.edu

Laurel Perweiler
Rochester Institute of Technology
Rochester, NY, USA
lmp2265@rit.edu

ABSTRACT

The use of gameful activities in education has been widely celebrated in recent years as an effective pedagogical method in engaging students, exciting cognitive abilities, and promoting mastery. Despite the popularity of game-based learning, to date, little has been done to analyze the impacts of introducing such interventions on students and instructors alike. We focus on hybrid teaching strategies that blend educational games with instructional scaffolding in introductory computer science teaching. We assess the effectiveness of incorporating these teaching strategies by leveraging various empirical evaluation techniques and study their impacts from three different dimensions: students' point of view, instructors' perspective, and students' performance. In addition, we establish correlations between students' approaches to learning and game-based learning, and further discuss how learning concentration and curiosity relate to students' perception of game-based activities.

CCS CONCEPTS

• **Social and professional topics → Computer science education**; *Computational thinking*.

KEYWORDS

Game-based learning; Learning Styles; Scaffolding; Introductory Computer Science

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1 INTRODUCTION

One of the most fundamental, and yet simple, structured educational activities is learning through game play. Games often engage cognitive reasoning, physical and gesture coordination, and psychological arousal. In the past few decades, games have been the center of attention in higher education as a means to teaching new concepts, fostering student interactions, and promoting critical thinking. The use of games in education to teach concepts is arguably motivated by its connection to the learning theory, and primarily, the *self determination theory* [6]. Gameful activities that target learners' intrinsic motivation by making activities "enjoyable" and fun also engage the learners emotionally, and as a result, improve cognition and critical thinking [23, 24].

In this paper, we focus on a particular type of game-based learning (GBL) activities. Our approach is to blend gameful activities with lesson planning to improve instructional scaffolding and promote a deeper level of learning. The goal is to use GBL activities as initial compelling tasks that not only engage students but also cultivate a challenging platform to raise student curiosity. Adopting a *modular* game design paradigm [11, 12], we develop game-based interventions in teaching introductory computer science courses that help improve student engagement. In particular, we focus on designing GBL activities for teaching the concept of 'graph traversal' to first year computer science (CS) students.

We assess the effectiveness of incorporating these teaching strategies by leveraging various empirical evaluation techniques and study their impacts from three different dimensions: students' point of view, instructors' perspective, and students' performance. The goal is to paint a wholesome picture on the impacts of gameful activities, particularly in computer science teaching. Formally, we are interested in answering the following questions about the impact of GBL in teaching introductory CS courses:

(1) Does GBL improve students' perception of learning, team work, and critical thinking? Do students perceive GBL as potential chaos and threat to the clarity of instruction?
(2) Is there any relationship between student learning traits and the perception of GBL activities?
(3) How do instructors perceive GBL in teaching introductory CS courses?

In addition, we are interested in establishing whether and to what degree students' perception of the GBL activities influence their responses to the core survey questions and whether students' approaches to learning and their attitude towards learning affect their perception of GBL methods in the classroom.

1.1 Our Results

This empirical study was conducted on first-year students in a large-scale institution involving ten sections and eight instructors. Sections were randomly assigned to the control and the study groups. We collected anonymous post-activity survey data, conducted semi-structured interviews with instructors, and analyzed students' grading performance.

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Our statistical analysis suggests that 1) students significantly perceived GBL positively with respect to learning, working in groups, and cultivating critical thinking, 2) there was no substantial correlation between students' attitude towards learning and GBL activities, 3) there was no significant difference between the study and the control group with respect to organization and clarity of instruction, and 4) students attitude towards concentration and critical thinking positively correlates to their perception of GBL activities and their acceptance of such methods.

1.2 Related Work

Game-based learning has been the center of attention among the educators and practitioners in higher education pedagogy [3, 7, 27] and K-12 education [5, 17, 26]. It has been seen as an effective way of improving students' motivation and engagement in the learning process through relevant gameful activities [9, 28]. There has been significant effort in the gamification domain to utilize digital or computer games for education purposes [4, 8, 16, 19, 21, 22, 26, 30]. Most of these works are inspired by the popularity of video games or computer games to improve learner engagement: teaching cybersecurity through computer games [18, 25], educational games for K-12 computing [15, 32], improving active learning for teaching data structure or algorithm concepts [8, 10], and developing game engines for entry-level classes in gaming [21, 31].

In contrast to computer-based approaches, traditional games tend to utilize the elements of games and gameful design for delivering CS concepts or improving assessments. The use of traditional games to teach concepts in computer science has been popularized in recent years, as a way to reconnect to fundamental notions of play. These approaches range from designing board games, puzzles, or other game modules with the objective of teaching concepts. For example, pencil puzzles (e.g. Sudoku) were proposed to encourage computational thinking in computer science assessments, which were shown to improve students' enjoyment and their perception of coding skills [1] while being gender- and experience-neutral [2].

We focus on the use of traditional gameful activities without the use of computers in classroom delivery as a means to promoting active learning and instructional scaffolding.

2 STUDY DESIGN

One of the preliminary, yet fundamental, concepts in teaching data structures in the first year sequence is graph traversal or graph search algorithms such as Breadth First Search (BFS) or Depth First Search (DFS). These algorithms are arguably the first techniques that students have to learn, and may be confusing at times for first time students. In particular, instructors reported several issues when teaching concepts (e.g. backtracking), making graph traversal a suitable topic for our study.

Going into the activity, students had a basic introduction and understanding of the fundamental concepts of graphs but were not yet introduced to traversal algorithms. The intended learning outcome of this topic are that students expected to 1) apply the steps of traversal on graphs, 2) distinguish between BFS and DFS and their applications, 3) apply and comprehend backtracking.

The lectures in the control group were usual standard lectures with occasional active learning methods such as question-answering, pair work, etc. The lesson planning in the study group started with an introduction about graphs, basic terminology, and a reminder of the past session followed by an interactive GBL activity (see details below). After the GBL activity, instructors explained the main concepts by making connections to the GBL activity. Finally, students partake in a post-assessment activity using Kahoot.

Table 1: A sample assignment of numbers to letters in COMPILE.

C	O	M	P	I	L	E
7	6	5	9	8	1	4

In order to introduce these concepts we introduced a game-based activity with the intention of studying the effectiveness of such interventions on students and instructors alike.

2.1 COMPILE

We designed an activity, called "COMPILE" that reflects various elements of games and gameplay for teaching graph traversal and backtracking, and includes elements such as randomization, props, team play, competition, and creative development. In designing our activity, we were inspired by a popular video game Fallout [29] in which players are tasked with unlocking certain "SPECIAL" powers. Each letter in "SPECIAL" has different levels to unlock, and depending on these values the next paths will be unlocked.

We designed a constrained graph with nodes corresponding to words and edges corresponding to paths between the nodes. The words can be chosen freely depending on the context. We chose the nodes with words that would foster creativity and students can relate to in a fun way. These words contained different CS-related terms and random instructor names. Figure 1 illustrates a sample version of the COMPILE graph. The actual graph contains about 75 nodes and more than 120 edges. Students were first tasked to assign numbers to each of the seven letters in "COMPILE", which in turn will act as constraints on the given graph (Table 1). Then students were asked to traverse the graph following these constraints. For example, when visiting the node 'M8', if the initial chosen value for the letter 'M' is less than 8, you are not allowed to collect that word and should either continue at a neighbor node or backtrack to find an alternate path. Below are the detailed steps of COMPILE:

(1) Assign a value (or level), between one and ten, to each letter in COMPILE, such that all seven letters sum up to forty. You are free to use a number more than once or not at all.
(2) Traverse the tree starting at the top node. You can only hit the node if you have a number greater than or equal to the associated letter. You may go back one level if you do not have the correct number associated with the letter.
(3) Collect words on your final traversal, i.e. the nodes from the path found from the start node to the end node.
(4) Create a story with collected words attached to the final nodes. This is equivalent to filling in the edges of a graph.

Once the (pre-identified) end node in the graph is reached, students in each group collect the words they hit on their final traversal and create a story. This is where freedom and creativity are granted. Students were able to utilize the words in any possible order to

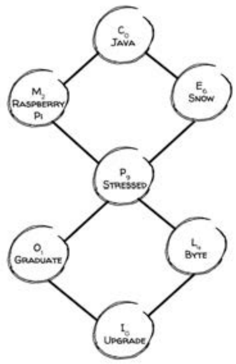


Figure 1: A sample version of the COMPILE graph. The actual graph contains about 75 nodes and more than 120 edges.

come up with a story to present to the class. The whole activity was completed in pairs of two, and the best (funniest) stories (by student votes) won candy prizes. Predictably, students in all participating sections were comfortable sharing their unique stories to the class due to a friendly and encouraging environment that was created through interaction, with several funny and engaging stories. For instance, one group created the following story:

"*It was a dark and stormy night at [X] institution. The evil professor [SMITH] was stuck inside finishing his next evil assignment. [SMITH] found that when he made students fail, it gave him a MAGIC feeling inside. After taking a swig of some JAVA, he proceeded to email his finished creation to Professor [DOE] and the rest of the CS department. Little did they know he know, that [DOE] and the rest of the department would STUDY his evil ways and also create their own evil exams and labs to destroy the hopes and dreams of the CS/SE student body. These new evil accomplices proved to be a big upgrade to his evil plot. After the evil [SMITH] puts forth his plan, he will make sure that no student ever GRADUATES.*"[1]

2.2 Post Assessment

The post-assessment activity was designed as a game module and was presented towards the end of the lecture as a fun approach to gauge students' knowledge of the covered content. In this post-assessment activity, students participated in a short ungraded quiz using Kahoot.it platform. Kahoot provides a fun gamified platform for online quizzes where students move up the ladder board by correctly and quickly answering the questions. Students participated by answering five multiple-choice questions, and the top 10 students received candy prizes. We would like to note that the participation was completely anonymous and students were given a chance to choose any nickname to enter the game using their computer devices (e.g. cellphones, laptops, tablets).

2.3 Evaluation Methods

We used a combination of questionnaires, grades, and semi-structured interviews with educators to investigate the effectiveness of the proposed GBL interventions.

[1] Names have been changed due to confidentiality.

Table 2: Descriptive statistics of students' responses grouped by category.

	Study		Control	
	μ	σ	μ	σ
About the lecture	5.24	1.38	3.88	1.68
Working together	5.05	1.35	3.90	1.30
Lecture opportunities	4.96	1.36	3.98	1.468
About you	5.14	1.39	4.73	1.4

We used post-activity online questionnaires to gauge students' perception of the proposed interventions. The set of questions were selected from the Experiences of Teaching and Learning Questionnaire (ETLQ) [14] into four main categories: About the lecture (9 questions), Working Together (7 questions), Lecture Options (6 questions), About You (7 questions), and an open-ended question for any additional comments or feedback. To ensure the reliability of the measure over the responses, we chose a 7-point Likert scale from strongly disagree to strongly agree.

3 EMPIRICAL EVALUATION

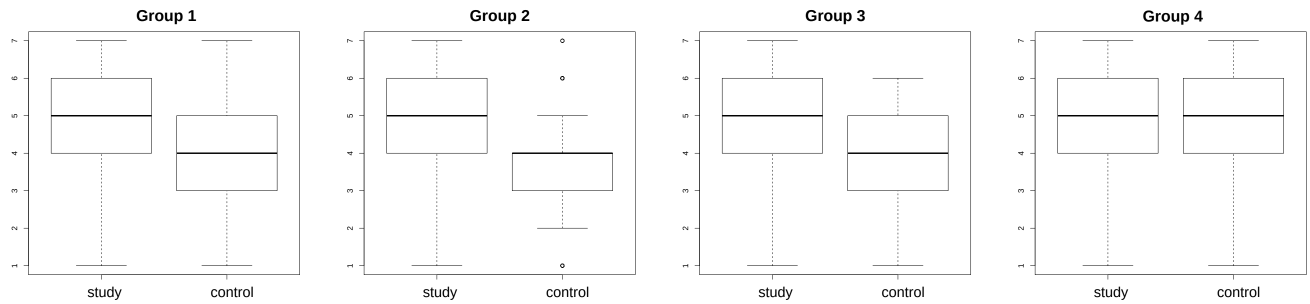
We conducted our study in a computer science course on data structure and design with an object-oriented perspective – the second course in an introductory CS sequence. The students were generally first-year computer science or software engineering students with basic knowledge about programming in Python and elementary data types and structures (e.g. stacks, queues).

We randomly selected 5 sections (out of 10) with 4 distinct instructors as our study (test) group, and the rest with 4 instructors as the control group. Each section of this course on average has about 44 enrolled students. The total of 57 ($\approx$ 28%) students from the study group and 25 ($\approx$ 12%) from the control group completed the voluntary and anonymous online questionnaire after the study. The low response rate is generally attributed to voluntary participation and not assigning any additional incentives (e.g. grades) for participating in the survey after the lecture. Table 2 illustrates the descriptive statistics of the responses in each category.

3.1 Statistical Significance Analysis

Since our data set contained several possibly correlated variables, we ran a Principle Component Analysis (PCA) between the responses to all 29 questions to find meaningful correlations between the responses. Only the first PCA (PC-1) provided meaningful explanation of the variance and explains about 50.9% of variables. Figure 3 illustrates the first and second components. Other principle components are more or less equal (and unsubstantial), implying that there is only one group of questions which correlate with each other, and it includes all but the 'About You' questions.

Although the control and study groups are not strictly divided by PC-1, their means are statistically different (Figure 3). The two samples have unequal variances and sample sizes (Figure 2), hence, we conducted a Welch two sample t-test. There was significant difference in the scores between the study group ($\mu = 5.42$) and the control group ($\mu = 2.065$); $t(45.05) = 4.488, p = 4.942e - 05$. These



(a) About the lecture **(b) Working together** **(c) Lecture opportunities** **(d) About you**

Figure 2: Box plots visualizing the statistical distribution of responses in every category.

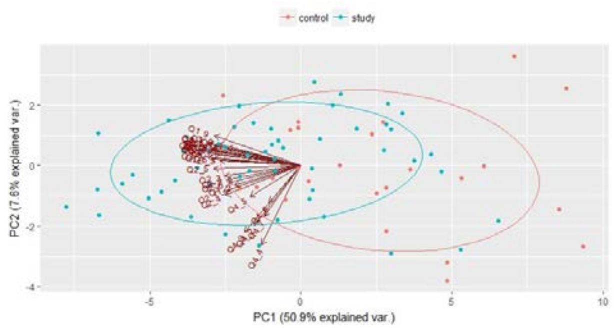


Figure 3: Principle component analysis for study and control groups. Only PC-1 and PC-2 are drawn.

results imply the study group had statistically significant positive perception of the game-based interventions with respect to lecture style, working with peers, and enjoyment of the lecture.

Although our initial analysis showed significant difference between the groups, it does not provide sufficient justification as to what factors influence these results. In the next section we further dissect the various parameters by relating to the learning theory and psychology of learning to paint a more vivid picture on the impacts of GBL interventions on students' perception of learning.

3.2 Detailed Analysis

In this section, we delve deeper into the pedagogical aspects of employing GBL in CS lesson planning and discuss the ramifications of our findings on a variety of key classroom dynamics.

With multiple comparisons (29 variables), we conducted unpaired two-sample t-test with Bonferroni correction. After this correction, the responses to most questions were statistically significant between the two groups except a few questions about communicating knowledge and ideas effectively, making relevant connections between topics, and discussing important ideas. One check question was included in the 'About You' section to ensure the accuracy of the collected data against *response bias* and remained significantly correlated to two other questions in previous sections. This means that students generally were sincere about their responses and completed questions accurately on average.

3.3 Enjoyment and Students' Interest

The students found the game-based interventions successful in creating a fun and enjoyable environment. There was a significant difference between the two groups (after Bonferroni correction) on all questions related to enjoyment and students' interest in the GBL activities. Students in the study group reported that the lecture helped them stay interested, was better than a typical class, provided plenty of opportunities to gain interest in the topic, and overall enjoyed the lecture. In fact, the probability values were among the strongest for all questions in this category ($p < 2.39e-05$). These results are consistent with previous research on positive impacts of GBL in educational context [4, 13], further confirming that play and games can raise cognitive arousal and improve students' motivation.

3.4 Working Together and Critical Thinking

Working with fellow classmates in university classrooms can sometimes be intimidating, particularly for first-year students. They are often scared or hesitant to work with others or may find group activities absurd without meaningful contribution to the learning process. Interestingly, we find out that working together towards a reasonable educational game can boost students' sense of group work while showing the benefits of working together. In particular, our analysis shows that students were generally comfortable with working with other students, felt that their views were valued among their peers, and in general during the lecture (statistical significance after Bonferroni correction $p < 0.0002$). Moreover, the lecture provided plenty of opportunities to work with others and develop the concept with the instructor and other students.

With respect to cultivating thinking and learning, students perceived the GBL lecture as a lecture that helped them improve their learning performance; encouraging them to focus on the topic. This stands in sharp contrast with a belief that incorporating game-based activities often distracts students from learning [20].

A few students commented about positive aspects of these activities in their critical thinking process. One student commented "*I believe this lecture generally helped me understand the topic of DFS and BFS. Visualizing the topic / using unique examples, in my opinion, help me to pay more attention and be more active in the lecture*".

3.5 GBL $\stackrel{?}{=}$ Chaos

Even though the empirical evaluations suggest that students strongly support the use of games and game-based activities, our further detailed analysis on responses suggests interesting revelations about students' perception of classroom dynamics.

First, there was no significant difference between the groups on the *clarity of instructions* and *clear linkage to the intended learning outcomes*. This finding suggests that both groups perceived the lectures similarly, implying that the GBL lecture did not introduce chaos or any confusion with respect to instructions and connections to the subject matter. Nevertheless, students reported that the GBL lecture did not provide plenty of 'opportunity for problem solving and discussing important ideas' nor 'working on technical procedures specific to the subject'. These findings suggest that students do not find GBL activities significantly different from regular lectures when it comes to technical details and procedures.

We should also note that all significance testing was done with Bonferroni correction. Interestingly, the responses to *all* of these questions (except the 'About You' section) were statistically significant without Bonferroni correction. The only response with statistically significant difference in this category (Lecture Option) was about motivation and gaining interest, i.e. "This lecture provided plenty of opportunities for me to gain interest in the topic.", with the study group ($\mu = 5.37, \sigma = 1.20$) and the control group ($\mu = 3.76, \sigma = 1.42$), $p = 1.49E - 05$. Thus, we postulate that, perhaps, the collected data does not have sufficient statistical power, motivating further studies to truly capture such relationships.

4 LEARNING STYLES AND ATTITUDES

Figure 4 illustrates the pairwise Pearson correlation for the study and the control groups. The horizontal and vertical lines denote the four groups of questions. These figures further confirm the significant correlation between groups 1 and 3, although the rest of the correlations are insignificant. Moreover, the correlations between group 4 (About You) responses and the rest of the responses is insignificant, which further confirms our initial PCA analysis.

4.1 Between-Group Analysis

A common natural question in the context of teaching strategies is to investigate whether students' perception of the new intervention is correlated to their learning styles and attitudes. To answer this question, we analyzed the correlation between the responses to the 'About You' questions. This section included explicit questions about students' (self reported) attitude towards learning: 'ideas in my academic reading often send me off on long chains of thoughts', 'it is important for me to follow arguments, or to see the reason behind things', 'when I communicate ideas, I reflect on how well I've gotten my points across', 'concentration is not usually a problem for me, unless I've been really tired', and 'on the whole, I am systematic and organized in my studying'. These standardized questions where directly adopted from ETLQ questionnaire [14].

The PCA analysis between the responses did not show any strong correlations between those answers, and a following t-test confirms that there is no statistical difference in these questions between the study and the control group. Moreover, no statistically meaningful correlation between these questions and other questions exists, implying that we cannot attribute students' perception of GBL or team work to their learning styles or personal factors. It is worth noting that there was also no significant correlation between any of the questions about the lecture or working together with whether students perceived to be doing well in this course in general.

4.2 Within-Group Analysis: Concentration and Critical Thinking

Our analysis showed that both groups had statistically similar attitude toward learning. The next interesting question is to draw the relationships between students' perception of GBL activities and their learning style and attitude towards information processing.

Our analysis reveals two strong correlations about students information processing and their responses to the questions about lecture style. First, students who responded strongly about their ability to concentrate and focus on topics also strongly supported that the GBL activities provided plenty of opportunities to communicate knowledge and ideas effectively and gain interest in the topic. Second, those who strongly stated that for them 'it is important to follow arguments, or to see the reason behind things' also strongly believed that the GBL lecture was relevant to the topic and enjoyable, found the lecture organized, and believed that working with other students helped them develop deeper understanding.

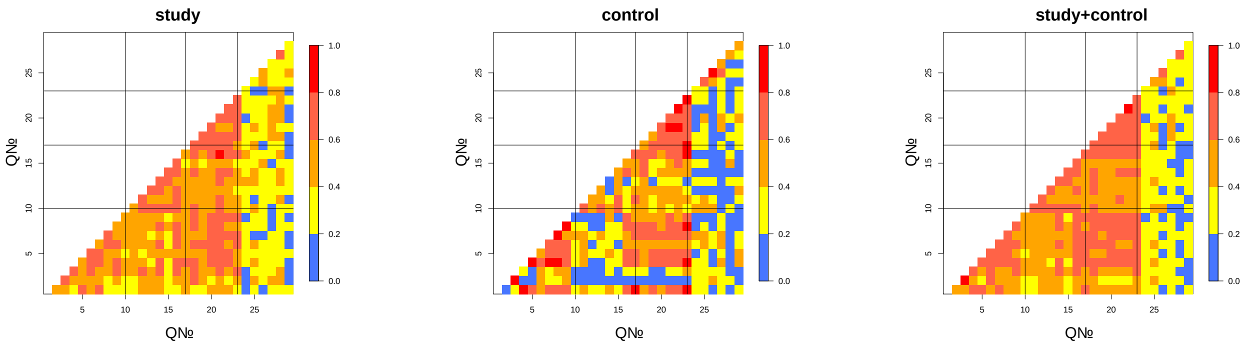
These results suggest that perhaps learners with improved focus abilities or those who value deep argumentative reasoning and critical thinking are more welcoming to gameful activities due to the inherent discover-and-advance feature of GBL activities.

4.3 Examining Student Comments

We also examined the open-ended comments to provide a more wholesome picture of students' experiences in the study group.

Overall, students generally enjoyed the GBL activities and enjoyed engaging with other students in the class; it helped them stay more focused on the material at hand. Most students, formally and informally, indicated that they were able to visualize the material that instructors were explaining afterwards. One student mentioned "*I thought the game was a fun break from the usual lecture. I really enjoyed the mini quiz at the end where everyone could participate. It not only engaged the class, but it would probably help the professor to tackle any misconceptions that students may have about the material right there. It was nice it was anonymous because I feel like people are too shy to ask questions*". Another student mentioned "*I believe this lecture generally help me to understand the topic of DFS and BFS. Visualizing the topic / using unique examples in my opinion help me to pay more attention and be more active in the lecture*".

As our statistical analysis showed, certain students connect with particular learning and delivery styles better than others. Few students reported that they could not relate the activities to the topic. One student commented "*I don't feel like I gained much knowledge from the lecture, but I think that had the game not been a component of the class I would have been able to learn more*". Another commented that "*There is already so much material to go over each lecture that the activity that didn't help us learn or review*". Even though these were not substantial, they convey a key message: there needs to be a serious attempt from instructors to harness the gameful activities and put effort in making meaningful connections to the concepts.



(a) Study group **(b) Control group** **(c) Study+Control group**

Figure 4: The pairwise Pearson correlation between 29 questions: colors indicate the absolute value of the Pearson coefficient.

4.4 Impact on Grades

To gain more insights into learning performance of students, we analyzed students' summative performance on the final exam as secondary data. The final exam questions were designed independently from this study. In fact, to avoid any type of bias, instructors were not informed about the possible collection of grades for further analysis. We did a post analysis of the questions in the final exam and identified six questions out of 23 total questions that were related to graph traversal algorithms. These questions ranged from multiple choice questions to comprehensive question.

We ran a two sample unpaired t-test between the total grades of students on the selected six questions about graph traversal. With respect to students' grades, there was significant difference between the students in the study group ($\mu = 25.52, \sigma = 26.12$) and the control group ($\mu = 23.67, \sigma = 27.37$); $t(131) = 2.10, p = 0.03$.

Despite this statistical confirmation, we refrain from making any immediate conclusions about learning performance and believe that these findings should be interpreted solely as encouragement for future studies on the impact of GBL on learning performance.

5 INSTRUCTORS' POINT OF VIEW

One of the pillars of any successful intervention in teaching strategies is educators' view point and tendency to adopt the newly proposed teaching methods. Therefore, we analyzed this dimension by conducting a series of semi-structured interviews.

A total of four instructors (out of 8) adopted the interventions in their classes (study group). The instructors who participated in the presentation of this experiment had generally positive feedback. They thought the lecture was way more interactive than any other previous lectures. One instructor stated how he had students in his class who had never spoken during in-class activities, who finally participated and spoke for the first time during the GBL lecture.

Another instructor stated that this form of lecture was like "*a breath of fresh air*" and that he would love to do more activities like this one, where "*rules can be taught quickly*". This instructor was quickly inspired by the game-based techniques he observed in "COMPILE" and started implementing short activities into the beginning and the end of his higher-level CS lectures.

While the presentation of this activity created a lot of excitement by trying a new teaching-style, it also led to some instructors being hesitant and nervous. One instructor spoke up by admitting his biggest fear was time management and not having sufficient time for the lecture, particularly because these lectures are heavily coordinated. However, he turned out to be "*pleasantly surprised at the end of the lecture-block when he did not run into that issue*".

These instructors mentioned that they are determined to adopt similar strategies in other CS courses. In fact, at the time of writing this article, three of the instructors have been revamping the first course in the introductory CS sequence by incorporating similar gameful activities into the recitation sections of these courses.

6 DISCUSSION

We investigated the effectiveness of incorporating GBL strategies from students' point of view, instructors' perspective, and students' performance. Our results suggest that i) students' significantly perceived GBL positively with respect to learning, working in groups, and cultivating critical thinking, ii) there was no substantial correlation between students' attitude towards learning and GBL activities, iii) students considered both lectures similar with respect to organization and clarity of instruction, and iv) students attitude towards concentration and critical thinking positively correlates to their perception of GBL activities.

Although there was a significant difference between the performance of the two groups, it is difficult to wholeheartedly count this as a success story. Several other parameters throughout the semester, such as instructors' teaching style, delivery of other topics, and the feedback on assigned homeworks, may impact the performance of students. As such, measuring the effectiveness of GBL interventions on learning outcomes requires a thorough controlled study over a long period of time and across various groups. We think that this is an extremely exciting, and yet challenging, future direction.

Finally, the choice of activity and game design, is heavily dependent on the subject matter, and even the topic at hand. Thus, a hybrid teaching method perhaps is superior to any single teaching strategy. Certain type of topics are naturally more suitable for such interventions; a point that was confirmed by the participating instructors.

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