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Learning IS Child's Play: Game-Based Learning in Computer Science Education

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Abstract

Game-based learning has received significant attention in educational pedagogy as an effective way of increasing student motivation and engagement. The majority of the work in this area has been focused on digital games or games involving technology. We focus on the use of traditional game design in improving student engagement and perception of learning in teaching computer science concepts in higher education. In addition, as part of an interdisciplinary effort, we discuss the interplay between game-based learning in higher education and disciplinary cultures, addressing the lack of empirical evidence on the impact of game design on learning outcomes, engagement, and students' perception of learning.

1. INTRODUCTION

Engaging students directly in the process of learning is one of the most fundamental approaches to achieve mastery in the learning process. Active learning methodologies have been celebrated in the past few decades as means of improving cognitive abilities and promoting deep learning through effective participatory engagement. Meyers and Jones (1993) describe active learning approaches as those that provide students the opportunity to discuss, interact and reflect on the content, ideas and issues of a subject [28]. Bonwell and Eison (1991) enlist a variety of teaching methods that promote active learning including peer-teaching, computer-based learning, cooperative learning, and games [3]. Since then, numerous experimental studies have proved the effectiveness of active leaning methods in engaging students and promoting mastery over their traditional counterparts in various diciplines and levels of education [1, 15, 23, 32].

Knowledge transfer and dissemination have long been recognized as crucial to advancing society. Ancient scholars and philosophers were aware of the significance of transferring ideas through institutional and individual education. Aristotle's emphasis on the challenges of effective education was prominent: "Learning is not child's play; we cannot learn without pain" (Aristotle, Politics, Book VIII). Aristotle's doctrine on education; nonetheless, was founded on learning by doing, reasoning, and reflection – "Anything that we have to learn to do we learn by the actual doing of it... We become just by doing just acts, temperate by doing temperate ones, brave by doing brave ones." (Aristotle Niconachean Ethics, Book II, p.91). Such learning is possible by involving learners in pleasurable activities that engage a deeper level of cognition. Fast forward to the current era, we argue that learning may in fact benefit from play, and thus, play could be key in effective education and high-level cognition.

In recent years, Game-Based Learning (GBL) has received significant attention from educators and researchers [6, 10, 17, 42]. It is an effective way of increasing student motivation and engagement [13, 45], and can be seen as a form of gamification targeted to improve learning. Gamification is the application of game elements and principles in non-game contexts [11, 20] with the goal of improving user engagement and productivity. The use of game design in educational and pedagogical development is intended to provide an engaging and participatory framework for learning. Game-based learning has been the focus of several recent projects to improve learning with the intention of making education more engaging and relevant, from public K-12 education supported by New York City Department of Education [8] to US military training [19], online education, and even public education of endangered animals [38].

The majority of the work on game-based learning is focused on pre-K and K-12 education, as a way of engaging children [22, 41], as well as on digital games or games using technology [7, 12, 21, 24, 25, 29, 30, 41, 46, 47]. However, not much has been done in exploring the impact of traditional game design in higher education, particularly in computer science education. In addition, the current literature on game-based learning does not provide concrete methodologies for deploying games nor provide a reasonable assessment of the effectiveness of game-based learning in higher education pedagogy. Thus, there is a critical need for formal and informal assessments of these novel pedagogical methods, and their suitability in various disciplines.

In this paper, we deviate from digital games and focus attention on the effectiveness of traditional game design in higher education pedagogy. Digital or computer-based games tend to create secondary objectives that are detached from the primary intended outcomes of teaching modules, which is learning and mastery of a subject matter. There is evidence that, when faced with digital games, students often get more concerned about game technology and mechanics such as the graphics of the game instead of educational purpose [27].

Our goal is to assess the effectiveness of games without the use of technology in higher education and study students' perception of learning and engagement. To gain deeper insights into students' learning, we empirically evaluate such educational interventions by providing statistical analysis of collected data, student surveys, and semi-structured interviews. Formally, we seek to explore the effectiveness of GBL in higher education pedagogy through the following questions:

1. Does game-based learning improve students perception of learning and mastery in higher education computer sciences classes?
2. Can game-based learning increase student engagement and teamwork in computer science courses?
3. Is there a relationship between the effectiveness of game-based learning in higher education and the disciplinary culture?

We first discuss our methodology in bringing games and gameplay to higher education pedagogy. In Section 3 we discuss the details of our study including the design, the details of the topics and teaching approach, and the mixed-evaluation method. Section 4 discusses our qualitative and quantitative results and their consequences, and provides answers to research questions (1) and (2). In Section 5, as part of an interdisciplinary effort, we focus on research question (3) and discuss a nuance interplay between game-based learning in higher education and the disciplinary culture through an empirical study in another discipline and contrasting the findings. Finally, in Section 7 we discuss the conclusions, lessons learned, and some of the drawbacks of our study.

2. GAME DESIGN AND LEARNING THEORY

In this paper, we focus on the use of games and gameplay in their most fundamental way without the use of technology and computer-based equipment. Games and game dynamics do not only incentivize learners to engage in the classroom, but also activate positive psychological arousal and increase the learner's focus and memory. When implemented correctly, fun group activities that induce a level of proficiency indirectly force the analytical cognition to capture the main ideas, create positive emotions, and stimulate and improve motor skills. Thereby addressing various domains of Bloom's taxonomy of learning [2]. Learners engage in problem solving and finding the best strategies (cognition [2]), get emotionally and psychologically aroused along with feeling a sense of community and competition (affection [39]), and employ various physical-mental coordination through motor skills (psychomotor [31]).

2.1 Design methods: immersive, thematic, or modular?

Games enable the integration of both intrinsic and extrinsic motivational components to cultivate an environment where players feel more motivated to engage in the target activities. In higher education, there are several ways to design effective game-based lesson plans to blend learning and play. The GBL design methods in general can be classified into three design types based on the granularity of activities: immersive, thematic, and modular game design.

Immersive game design encompasses the entire session (or series of sessions) as a full-fledged game where students participate in playing a game-based activity, and every activity is a game activity. The International Council for Local Environmental Initiatives (ICLEI) Canada's *Downspouts and Ladders* is one example where participants pro-actively address the negative impacts of climate change. In Ted Alspach's *Suburbia*, participants grapple with social, economic and environmental challenges of urban and suburban planning. See [36] for more examples of such games.

In thematic game design, students choose a character and points or badges are assigned to several of the dedicated activities throughout the semester. Students progress throughout the semester to develop their characters and social status within the full game. In contrast, modular game design focuses on gamifying a single activity by designing game modules that are independent of one another. Students get engaged in various game modules and move to another activity or section of the session after the game. The instructors can include one or several independent activities in a single session and there is no need for continuity. *Modular* game design can include a wide range of activities from memory games with playing cards to elaborate scavenger hunts.

2.2 Connections to learning theory

The *self-determination theory*, pioneered by Deci and Ryan [9], clearly distinguishes the motivation behind various reasons and goals that lead to an action. Although there are various factors and types of motivations, the two key basic categories are intrinsic and extrinsic motivations. In education, intrinsic motivations refer to education tasks or activities that are inherently enjoyable and interesting while extrinsic motivations separate the outcome of a learning activity from its inherent nature. More specifically, a learners motivation is derived from a distinct outcome such as a grade. On the other hand, intrinsic motivations result in high-quality learning and creativity [35], and games can engage learners through psychological arousal and engaging them in “enjoyable” activities.

Although immersive and thematic methods for gameplay appear not to be linked to traditional summative assessments, in practice, they often employ similar techniques such as points and ladderboards to encourage competition and participation in class activities. These comparators often get converted to summative assessments either through direct conversion to grades or indirect mappings to individual’s social/academic status in the learning environment.

Such indirect assessment techniques tend to “pointify” the game-based activities [14, 16, 34]. Inherently, pointification [16, 34] is a type of summative grading with an extra layer between learners and grades. Points, just like grades, act as extrinsic motives for learning and can redirect students’ attention from deep learning to collecting points for the sake of points. However, extrinsic rewards such as points and grades can also have negative impacts [5, 33, 35, 40].

The choice of design in GBL depends on the subject matter, class time, number of students, and the discretion of instructors. Modular activities are easier to implement and often more practical because tasks or activities are not required to contribute to the same theme. On the other hand, immersive and thematic activities can create a sense of community and social connection through continuity and cohesiveness.

We focus on modular game design as the most versatile and agile approach that can be easily adopted in hybrid curricula, and study its impact on students’ perception of learning, engagement, and team work. The independence between modules (or activities) also makes this type of game design more suitable for escaping from extrinsic motivations such as point. Students participate in the modules solely on the basis of intrinsic social and entertaining values[1].

3. STUDY DESIGN

This study was designed to explore the effectiveness of game-based learning techniques in improving students' perception of learning, engagement, and teamwork. Since one of the main objectives of this study was to measure students' perception of learning and engagement, we conducted the study in the same group of students while varying the teaching method on two different topics.

To accomplish this task, two lectures in an undergraduate course, namely "Data Types and Structures", were delivered, one using traditional lecture-style methods and the other one using game-based techniques. The two lectures were delivered one week apart and we gathered student feedback through an online questionnaire and semi-structured interviews.

To select specific lectures, we identified two topics that were similar in terms of pedagogical outcomes, level of difficulty, and the required background knowledge, while ensuring that the topics were sufficiently distinct so that the order of delivery (which topic is being taught first) had minimum influence on the outcome. This was done by reviewing previous offerings of the course, analyzing students' performance, as well as ensuring that topics stand independent of others in the course. Both lectures intend to target knowledge, comprehension, and application levels of Bloom's taxonomy of learning. The first topic was delivered using traditional teaching techniques with some active learning components (e.g. question-answering and pair work). The second topic incorporated modular game-based activities. Throughout this paper, we will refer to the former as "regular" and the latter as "game-based".

[1] The performance on these activities do not necessarily contribute to students' grades or has minimum impact.

The first lecture (regular) was an introduction to trees and tree traversal. The lecture had two primary intended learning outcomes, outlined below, relying upon instructor-led lecturing and some active learning activities that included question-answering, one pair work activity, and one group work activity where students were assigned non-competitive tasks on tree traversal problems. By the end of this lecture, students should be able to:

- Apply various traversal algorithms on binary trees and identify the application of each of the traversal algorithms, and
- Comprehend and analyze the binary tree traversal algorithms for search, namely breadth-first and depth-first search methods.

The second lecture (game-based) was an introduction to sorting algorithms with two intended learning outcomes: By the end of this lecture, students should be able to:

- Identify and apply various sorting algorithms, including bubble sort, insertion sort, selection sort, and merge sort, and
- Analyze the worst-case running-time of the sorting algorithms and devise the steps for sorting unsorted arrays.

The goal is to design algorithms that are (1) correct (applicable to any set of ordered elements) and (2) fast (in terms of number of steps required), under some mild assumptions. In our modular game-based lecture, we considered two game modules. In the first activity, the students were given a deck of cards and instructed to develop a method (algorithm) to sort the cards under the following rules: cards are seen one at a time, and in each turn (actions) you can only do one comparison between two cards. Groups were asked to write down the steps and keep track of the necessary steps.

Figure 1: Students were asked in groups to develop a method to sort the given cards with the fewest number of steps.

A few groups were randomly chosen (using dice) to send their representatives to the board and explain their algorithms. The teams with the best algorithms received candy as prizes. Interestingly, even though the majority of students had no prior exposure to sorting algorithms, teams developed algorithms resembling Bubble sort, Selection sort, Insertion sort, and even Merge sort. One team was working on developing a secondary algorithm that resembled Quick sort, but eventually was unsuccessful in defining a proper way for choosing a ‘pivot’.

The second game module 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 where students paired up in a friendly competition. Student participated by answering five multiple-choice questions, and the top 10 students received candy prizes. Sample questions used in the post assessment can be found in Appendix A.

Throughout the game-based sessions, we observed more active participation from students who were often silent and tend to participate in fewer activities in previous sessions. In fact, one of the most passive students got very excited and started to volunteer himself to share his solutions. We observed a similar trend about female students that became more engaged in the gameplay and group activities. These observations suggest that perhaps game-based activities are capable of involving a more diverse set of students with variety of learning types and behavioral traits.

3.1 The mixed evaluation model

We designed a mixed evaluation model to better capture the significance of deploying gamebased learning techniques. The mixed evaluation model gives a more comprehensive insight into investigating the hypotheses regarding the proposed approach. We used a combination of surveys and questionnaires, semi-structured interviews, and secondary data analysis.

After the lectures, students were asked to voluntarily participate in online surveys outside the class time. The surveys started with a set of questions regarding the general characteristics of the students adopted from the “Experiences of Teaching and Learning Questionnaire” (ETLQ) questionnaire [18]. In this section, we asked the students to state the degree to which they agree or disagree with the statements on a standard 9 Likert scale from Do not agree = 1 to Completely agree = 9; For instance, “It is important for me to follow arguments, or to see the reason behind things.” The questionnaire was organized into four sections: About You, About the Lecture, Working Together, and Opportunities. The questions were all adopted from ETLQ questionnaire, each designed to measure various aspects of teaching, followed by a free form to provide students an opportunity to freely share comments about the lectures or teaching styles.

The first section, About You, asked a set of questions regarding the general characteristics of the students, such as “On the whole, I am systematic and organized in my studying.” These questions were asked to gauge the study habits, self-confidence and overall perspective of the students’ own abilities. The subsequent sections were each designed to measure various aspects of the teaching and learning experience. This included questions regarding the students’ perceptions of the clarity, organization and effectiveness of the lecture, effectiveness of peer-instruction and interaction, and the opportunity to engage critically with the material.

The order of questions regarding the lectures (i.e. the game-based lecture and the regular lecture) was randomized, meaning that, half of the students were first asked about the game-based lecture and the other half first were asked about the regular lecture. Furthermore, the order of questions within each set were randomized to ensure that the presentation of the questions was not subject to ordering bias.

In addition to the questionnaire, semi-structured interviews were also conducted with volunteer students. In the next section, results and analysis from the online questionnaire are presented followed by the qualitative analysis of the semi-structured interviews. The analysis of both the surveys and the interviews is provided in the following sections.

4. ANALYSIS

The focus of our study was to investigate the impacts of game-based learning on students' perception of learning as well as on engagement and teamwork. In this section, we outline our findings, discuss the significance of our results, and provide the insightful observations obtained throughout this study that can help form intriguing hypotheses for future research.

Out of 90 students, 48 (53%) fully responded to the online questionnaire. The responses to the questionnaire depicted various interesting insights: in both lectures, students found the content well organized and structured and saw clear relevance of the activities with the subject matter, countering the myth that the use of games and game-based activities often leads to chaos and misunderstanding in the learning process. Furthermore, on average students favored the gamebased lecture and found this lecture more engaging. They reported that their enjoyment, peer interaction, and ability to share ideas were more pronounced in the game-based lecture. Figure 2 illustrates the questionnaire results contrasting the regular and game-based lectures across several categories.

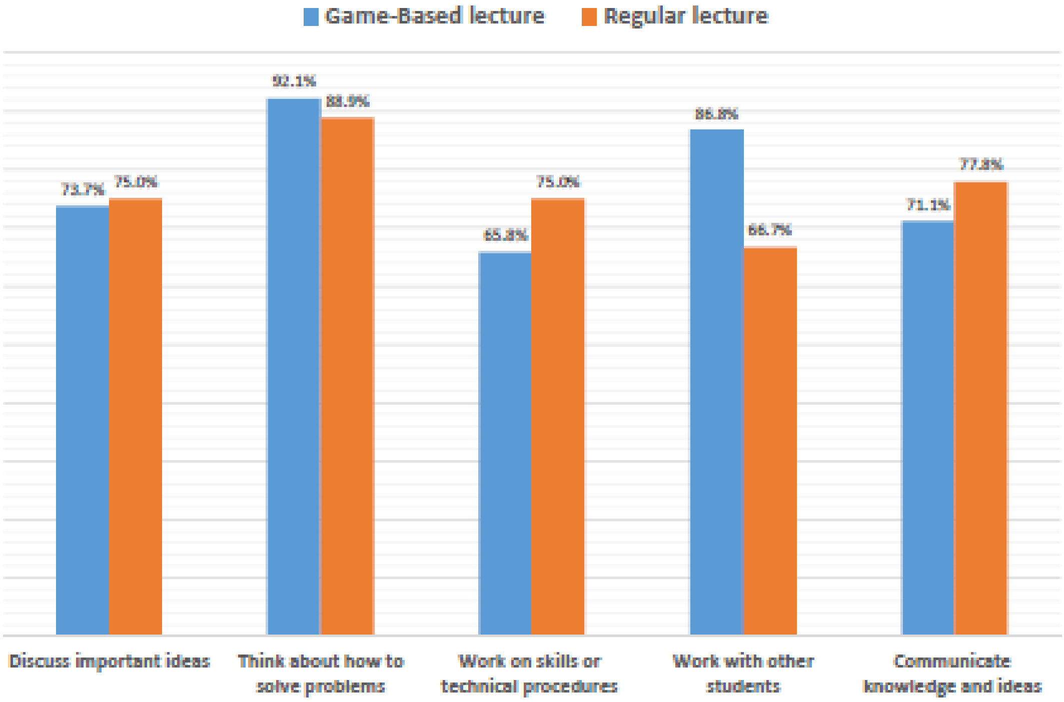

Figure 2: Summary of computer science students responses to the online questionnaire.

4.1 Students' perception of learning

In addition to the descriptive analysis, we also conducted a statistical analysis of the questionnaire results. We defined a score for each section based on the average of responses of students to all the questions in each section.

The questions about students' perception of learning are shown in Table 1. A paired-samples t-test was conducted to compare the students' perception of learning in the game-based lecture and the regular lecture. Even though students slightly favored the game-based lecture with respect to learning, there was not a significant difference in the general scores for the students' perception of the game-based lecture ($M = 7.83$, $SD = .85$) and the students' perception of the regular lecture ($M = 7.60$, $SD = 1.09$); $t\ (33) = 1.807, p = 0.080$[2].

[2] The use of non-parametric tests may be more appropriate for studies with categorical data; however, given that we used a 9-point Likert scale measure and the use of average score for participants' answers to question in each category, the sensitivity of testing variables are not crucial, and the results remain robust with respect to violeations of the assumptions of parametric tests. Nevertheless, we additionally conducted a series of non-parametric tests including a series of Wilcoxon signed-rank tests and a Spearman's rank correlation test. All results and conclusions remain the same and can be found in Appendix C.

Table 1: Students' responses to questions about the lecture styles

	Lecture Style	Mean	SD	P Value
It was clear to me what I was supposed to learn in this lecture.	Game-Based	8.03	0.94	0.46
	Regular	7.70	1.22	
What we were taught seems to match what we were supposed to learn.	Game-Based	8.12	0.91	0.096
	Regular	7.82	1.24	
The lecture was well organized and ran smoothly.	Game-Based	8.06	0.95	0.184
	Regular	7.88	1.09	
I could see the relevance of most of what we were taught in this lecture.	Game-Based	8.08	0.96	0.269
	Regular	7.88	1.09	
I felt encouraged to rethink my understanding of some aspects of the subject.	Game-Based	7.47	1.37	0.065
	Regular	7.05	1.68	
We weren't just given information, we developed it with the instructor and each other.	Game-Based	7.27	1.46	0.402
	Regular	7.51	1.32	
I enjoyed this lecture	Game-Based	7.97	1.22	0.018
	Regular	7.43	1.72	
General students' perception score	Game-Based	7.84	0.85	0.08
	Regular	7.60	1.09	

4.2 Working together

We defined a score based on the average of responses of each student to these questions. A paired-samples t-test was conducted to compare the students' perception of working together in the lecture in the game-based lecture and the regular lecture. There was a significant difference in the general scores for the students' perception of the game-based lecture (M = 7.16, SD = 1.40) and the students perception of the regular lecture (M = 6.83, SD = 1.46); t (32) = 3.224,p = 0.003. These results imply that students believe that game-based lectures are more effective in working together as opposed to the regular lecture.

Table 2: Working together

	Lecture Style	Mean	SD	P Value
Students supported each other and tried to give help when it was needed.	Game-Based	7.12	1.67	0.147
	Regular	6.90	1.72	
Talking with other students helped me to develop my understanding.	Game-Based	6.68	2.02	0.109
	Regular	6.47	2.016	
Students' views were valued in this lecture.	Game-Based	7.77	1.41	0.61
	Regular	7.68	1.44	
I found I could generally work comfortably with other students in this lecture.	Game-Based	6.87	2.04	0.07
	Regular	6.42	2.22	
Overall working together score	Game-Based	7.15	1.40	0.003
	Regular	6.83	1.46	

4.3 Correlation between learning traits and students' perceptions of the lecture

We studied the correlation between various questions to gain deeper insights between various factors involved in students' perception of learning, working together, and self-reported personal traits (Appendix B). Our Pearson correlation analysis generally showed few negative correlations between some variables such as ability to concentrate and the perception of talking to other students ($r =, -0.105, n = 38, p = .531$); however none of the negative correlations were statistically significant.

On the other hand, we observed several statistically significant positive correlations between various variables. For instance, being systematic and organized was positively correlated with five variables, including the clarity of the game-based lecture ($r =, 0.318, n = 37, p = .055$), learning expectation ($r =, 0.574, n = 37, p = 0.0$), and the students' perception of active learning ($r =, 0.333, n = 36, p = .047$). Intriguingly, following arguments and understanding reasons behind things positively correlated with all the questions and the correlations were statistically significant across six different categories including clarity, value of the lecture, enjoyment, and the expectation of the lecture (see Appendix B for the detailed analysis). These findings, although unable to identify the exact causal relationships, illustrate interesting correlation between students learning traits and game-based activities and raise several interesting questions for future research. In Section 7 we describe a few of the aforementioned open research directions.

4.4 Descriptive analysis

We used semi-structured interviews to gain deeper insights into students' perception of learning and collect more accurate reflection of students' preference about lecture styles. In terms of clarity of learning outcomes and lecture organizations, most students were indifferent between the GBL lecture and the regular lecture. This is an interesting finding since active learning methodologies, and in particular game play, is often considered as unorganized and "a recipe for chaos" [4, 37].

Nonetheless, one student mentioned that games may be stressful at times while better mimicking a real-life scenarios:

> "...when you play the game you do something in real time which sometimes get stressed out and stuff, which I think is similar to real life, but in standard lecture you take it a bit slow. But for the game, he [the instructor] explained everything while the game was done."

The same student found this aspect of games more memorable and relevant to real life saying "I was cooking something, and I was chopping onions, so I was thinking about CS, how to do searching and sorting..."

Students generally had a positive feeling about the GBL lecture and the opportunities to work in groups. However, there is a little fear of new teaching methods among a couple of students. One student mentioned "first time it may look very tough, but after the game instructor explained and you see how it was easy." When asked about which method you prefer, generally students found both methods effective with no strong preference, but one student mentioned that "it depends how good the prof is; a combination of both methods will be better." Adding that the game "gives you the opportunity to think." Evidently, some students found games more interesting when they are doing well in them, stating that "when you are winning, you actually enjoy it more!" The goal of GBL is to create activities that are enjoyable for everyone, regardless of winning or losing. Nevertheless, it may be impossible to separate achievement from competition as it is one of the key elements of game design. Therefore, an intriguing research question arises: What is the connection between emotions in winning/losing with the design principles used in game-based activities? We leave this as an open question for future research.

In addition, students found working in groups quite effective with one caveat, which is the choice of your groupmates. One student states "it depends on your partner; the least effective part is when your partner doesn't want to participate". These findings further highlight the importance of peer interactions in collaborative learning environments [26, 44]. With respect to time management, students prefer more time for GBL activities. One student mentioning that "...sometimes you want to come up with new ideas that are a bit better, but you don't have enough time." Allotting sufficient amount of time to students to think and reflect on problem is a challenging task. Particularly because computer science courses are heavy and loaded with subjects that must be covered according to the curricula. Although we leave this as an open discussion, we believe that modular game design, as we argued in Section 2.1, provides more flexibility for inclusion of GBL activities within heavy computer science curricula.

5. AN INTERDISCIPLINARY COMPARISON

This study emerged from a collaborative interdisciplinary project between the School of Computer Science and the School of Planning. Similar to the computer science, a parallel study with two lectures, one game-based and one regular, was conducted in an undergraduate planning course, "Introduction to Planning Analysis". The first (regular) lecture was an introduction to regressionbased population forecasts. The lecture had three intended learning outcomes: students will be able to (1) explain the regression-based forecast method, (2) calculate simple forecasts using linear regression, and (3) explain how regression-based forecasts inform the planning process. The second (game-based) lecture was an introduction to cohort-based population forecasts. The intended learning outcomes of the lecture were for students to be able to (1) explain the cohort-based forecast method, (2) calculate simple forecasts using cohorts and changing demographic factors, and (3) explain how cohort-based forecasts inform the planning process. Fewer students completed the online questionnaire with a response rate of approximately 30% (19 out of 60), and four students volunteered to participate in short semi-structured interviews.

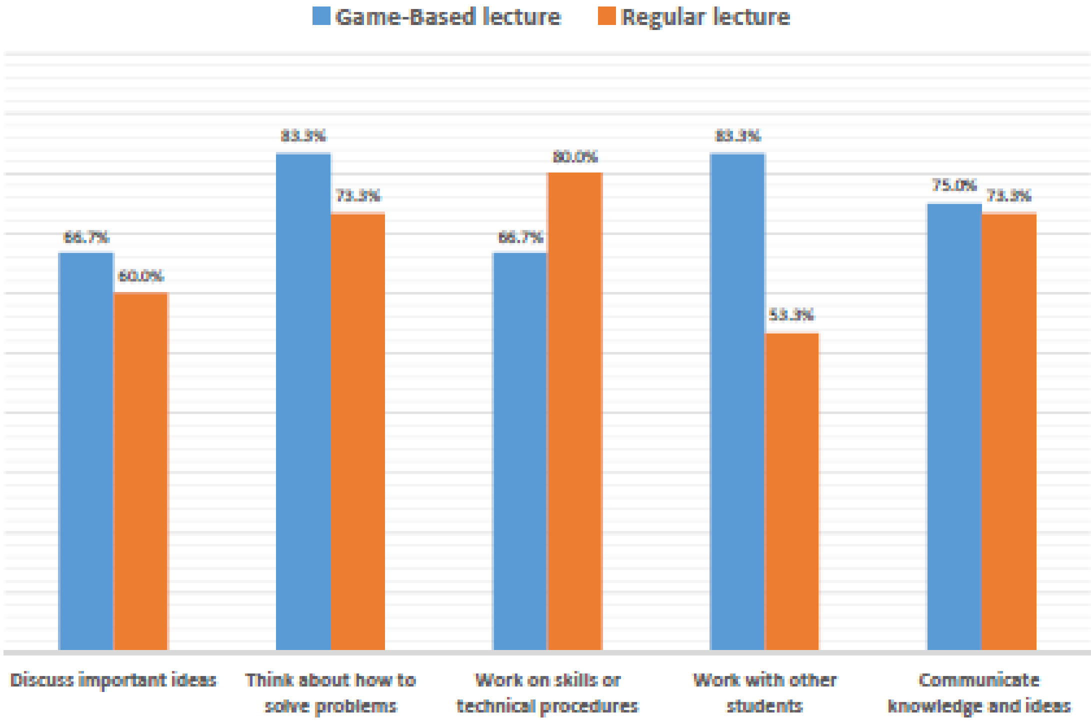

Figure 3: Summary of planning students responses to the online questionnaire.

In harmony with the CS students, the questionnaire results from the planning students (Figure 3) show relatively high scores across all questions in both lectures. Similar to CS students, the planning students felt that the game-based lecture was more effective for thinking about how to solve problems and less effective when working on skills or technical procedures specific to the subject. However, the statistical analysis of the planning questionnaire responses did not yield any significant result in any aspects of perception of learning or engagement and teamwork.

Regarding the students' perceptions of the lectures, there was not a significant different in the general scores of the traditional (M = 7.75, SD = 0.72) and game-based (M = 7.97, SD = 1.14) lectures. Similarly, there was not a significant difference between the students' perceptions of working together in the traditional (M = 7.73, SD = 1.05) and game-based (M = 7.96, SD = 0.59) lectures. The relatively high scores across all questions in both lectures barred any statistical significance. Nevertheless, the semi-structured interviews revealed several interesting insights into students' opinions and perspectives.

5.1 Interviews

Students generally enjoyed both lectures, and it was revealed during the interview that some students found the game-based lecture memorable. One student noted “[the regular lecture] was good, it was standard. Nothing special. It was fine. Moderately effective. If you compare it to the [game-based] one, it was less effective. I will always remember the game lecture, but the material from the [regular] one will fade in my memory.”

Despite not statistically significant results, one student mentioned that “[In the traditional lecture], I took notes, I asked questions. I didn’t talk to my peers, because when you are in a lecture, you are usually listening. [In the game-based lecture], I got to help out. I found myself really wanting to talk to my peers about the material and I was excited.”

However, a couple students highlighted their learning traits as the key reason behind their slight preference over regular lectures: “[regular] presentation is more effective for me because it allows me to sit down and focus on the content itself. I don’t have to worry about other factors such as following rules of the game or participating with other classmates.”

5.2 Learning goals and disciplinary cultures

The comparative results across these two relatively distinct disciplines provide additional insights into understanding the use of game-based learning in higher education. First, the planning students’ consistent preference for regular lectures when learning skills or technical procedures suggests that game-based techniques should not be haphazardly applied across the board. The instructional strategy must match the type of knowledge to be learned [24]. Moreover, as highlighted by Tu et al. [43], the teaching approach must stem first and foremost from the learning goal. Goal setting creates the framework from which environment design, rules, dynamics, rewards and all other components follow, if and only if, game-based learning is an appropriate approach. Second, the nature of the course and the disciplinary culture affect how students perceive, and subsequently response, to various pedagogical methods. Even though the CS students did not show a general preference over game-based learning methods, they found the game-based lecture more enjoyable, and more importantly, more effective in classroom engagement, teamwork, and ability to think analytically. However, they felt that they received less guidance from the instructor throughout the gamebased activities and found the regular lecture to be marginally more effective for communicating knowledge and ideas. Whereas planning, as a professional discipline, requires significant interaction, negotiation and collaboration with other individuals and parties by nature.

6. FURTHER DISCUSIONS

In this section, we discuss the limitations of our study and provide a few informal observations that can shape further studies in this area.

6.1 Limitations

Our empirical findings shed light on students' perception of learning and engagement towards GBL interventions. Students' active participation and engagement in class has shown to affect their performance and learning. However, this indirect link to the effectiveness of GBL methods cannot be justified through our study, and requires further controlled studies through, perhaps a longitudinal pre and post-test analysis between groups. Our study was limited by design and funding in scope. Moreover, we conducted the study on the same group of students and varying the subjects, rendering the teaching method as a control variable. These design constraints can potentially impact our findings. Thus, increasing the scope to a larger study and multiple classrooms, with a controlled group on the same topic can reveal more interesting insights into the effectiveness of GBL methods as viable intervention method for classroom engagement and mastery.

6.2 Observations: learning traits and diversity

The game-based lecture provided additional insights into student engagement. Throughout this session, we observed more active participation from students who were often silent and tend to participate in fewer activities in previous sessions. In fact, one of the most passive students got very excited and started to volunteer himself to share his solutions. We observed a similar trend about female students that became more engaged in the gameplay and group activities. These observations give rise to a few hypotheses about the influence of learning traits, and the importance of multimodal pedagogical methods. The inherent nature of GBL activities in engaging various learning domains, from cognitive engagement through thinking and problem solving to visual, auditory, and even tactile stimuli along with the elements of meaningful social interaction, provides a solid framework for cultivating a richer learning environment for a diverse set of students.

7. CONCLUSION AND FUTURE DIRECTIONS

We deviated from digital games and focus attention on the effectiveness of traditional game design in higher education pedagogy. There is a critical need for formal assessment of such teaching paradigms in higher education. We aimed at addressing three key questions (Section 1) through formal analysis of students' responses as well as informal semi-structured interviews. Our goal was to assess the effectiveness of games without the use of technology in higher education and study students' perception of learning and engagement. To gain deeper insights into students' learning, we empirically evaluated such educational interventions by providing statistical analysis of collected data, student surveys, and semi-structured interviews. In addition, as part of an interdisciplinary effort, we discussed the interplay between game-based learning in higher education and disciplinary cultures, addressing the lack of empirical evidence on the impact of game design on learning outcomes, engagement, and students' perception of learning.

Our findings generally provided positive responses to the motivating questions in Section 1 regarding the effectiveness of GBL in higher education. We showed that (1) GBL activities in fact improve students perception of learning and mastery in higher education CS classes, and students are generally in favor of organized use of such methods, (2) GBL increases students engagement and teamwork compared to traditional active learning activities, and (3) the success and effectiveness of

GBL methods depends heavily on the disciplinary culture and the subject matter, and instructional strategies must match the type of knowledge and the subject matter.

The use of game design, and in general GBL, in engaging students and blend learning with the element of play has been successful in various contexts [8, 24, 47]. However, our findings shed light into intricacies of adopting GBL and suggest that educators and practitioners should consider the type of game design (immersive, thematic, and modular), motivating factors, learning styles, as well as disciplinary culture. If implemented correctly with careful consideration, GBL can be an effective tool for modern education filled by constant interruptions. And learners will definitely enjoy blended methods of teaching in computer science classes.

The crux of our study was investigating students' perception towards learning and working together in traditional GBL activities. Yet, we refrained from discussing the impact of game play in student's performance. Evaluating learning requires a tactful study design to truly capture learning even beyond grades. Thus, we see this as a promising future direction that requires a careful study design with a larger scope. The effectiveness of teaching methodologies such as GBL depends on various factors including disciplinary culture and the type of subject matter. One interesting future direction would be to investigate the perception of learning among students from other STEM fields.

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APPENDIX A: Sample of post-assessment questions

- What is the worst-case running time of the Merge sort?
- What is the best-case running time of the Merge sort?
- Which one runs faster, bubble sort or selection sort? think about the number of operations....
- What is the Big-O complexity of Insertion sort, if in each iteration we use Binary Search?
- A CS234 student has created a comparison sorting method with O(n). Do you believe him/her?

APPENDIX B: Statistical correlations

Correlations

		A It was clear to me what I was supposed to learn in this lecture.	A What we were taught seems to match what we were supposed to learn.	A The lecture was well organized and ran smoothly.	A I could see the relevance of most of what we were taught in this lecture.	A I felt encouraged to rethink my understanding of some aspects of the subject.	A We weren't just given information, we developed it with the instructor and each other.	A Students supported each other and tried to give help when it was needed.	A Talking with other students helped me to develop my understanding.	A Students' views were valued in this lecture.	A I found I could generally work comfortably with other students in this lecture.	A I enjoyed this lecture1.	It was clear to me what I was supposed to learn in this lecture.	What we were taught seems to match what we were supposed to learn.	The lecture was well organized and ran smoothly.	I could see the relevance of most of what we were taught in this lecture.	I felt encouraged to rethink my understanding of some aspects of the subject.	We weren't just given information, we developed it with the instructor and each other.	Students supported each other and tried to give help when it was needed.	Talking with other students helped me to develop my understanding.	Students' views were valued in this lecture.	I found I could generally work comfortably with other students in this lecture.	I enjoyed this lecture2.
On the whole, I am systematic and organized in my studying	Pearson Correlation	0.249	0.269	0.209	0.121	-0.082	-0.068	0.169	0.072	.437**	0.204	0.251	0.318	.574**	.447**	0.308	0.172	.338*	0.184	-0.009	.614**	0.098	0.283
	Sig. (2-tailed)	0.116	0.098	0.196	0.458	0.616	0.764	0.298	0.661	0.005	0.213	0.134	0.055	0.000	0.008	0.063	0.308	0.047	0.282	0.957	0.000	0.575	0.100
	N	41	40	40	40	40	40	40	39	39	39	37	37	37	37	37	37	36	36	35	35	35	35
Ideas I come across in my academic reading often send me off on long chains of thought.	Pearson Correlation	0.247	0.046	0.153	0.201	.358*	.336*	.397*	0.298	0.208	0.120	.440**	0.113	-0.050	0.169	0.219	.375*	0.137	.457**	.423*	0.058	.442**	.359*
	Sig. (2-tailed)	0.119	0.782	0.345	0.214	0.026	0.033	0.011	0.067	0.208	0.466	0.006	0.507	0.770	0.317	0.193	0.022	0.427	0.005	0.010	0.743	0.008	0.034
	N	41	40	40	40	40	40	40	39	39	39	37	37	37	37	37	37	36	36	35	35	35	35
When I communicate ideas, I relied on how well I've got my points across.	Pearson Correlation	0.299	0.260	0.137	0.257	0.098	0.206	0.074	.361*	.501**	0.134	0.123	0.013	0.000	0.125	0.021	0.085	0.205	0.305	.406*	0.233	0.246	0.251
	Sig. (2-tailed)	0.068	0.115	0.412	0.153	0.557	0.215	0.661	0.026	0.001	0.429	0.473	0.941	1.000	0.476	0.906	0.626	0.244	0.079	0.017	0.191	0.171	0.151
	N	38	35	38	35	38	38	38	38	35	37	36	35	35	35	35	35	34	34	36	33	35	34
It is important for me to follow arguments, or to see the reason behind things.	Pearson Correlation	.394*	0.245	0.256	.451**	0.140	0.281	0.286	0.116	.397*	0.107	.536**	.391*	0.191	.353*	0.276	0.192	.409*	.385*	0.131	0.227	0.213	.562**
	Sig. (2-tailed)	0.014	0.147	0.126	0.005	0.410	0.091	0.086	0.494	0.015	0.533	0.001	0.022	0.279	0.035	0.115	0.276	0.018	0.024	0.486	0.203	0.238	0.001
	N	38	37	37	37	37	37	37	37	37	36	35	34	34	36	34	34	33	34	36	33	35	34
Concentration is not usually a problem for me, unless I've been really tired.	Pearson Correlation	0.149	0.068	0.017	0.056	0.041	0.073	0.086	-0.105	-0.202	0.309	0.153	0.201	0.142	0.182	0.060	.421*	0.304	0.140	-0.038	0.111	.374*	0.236
	Sig. (2-tailed)	0.385	0.709	0.918	0.757	0.807	0.665	0.609	0.531	0.229	0.063	0.372	0.246	0.414	0.296	0.731	0.012	0.081	0.429	0.835	0.538	0.032	0.180
	N	38	35	38	35	38	38	38	38	35	37	36	35	35	35	35	35	34	34	36	33	35	34
If I've not understood things well enough when studying I try a different approach.	Pearson Correlation	0.060	0.010	-0.144	0.003	.420**	0.123	0.167	.475**	0.209	0.294	0.087	0.037	0.216	0.191	0.052	.452**	0.225	0.147	.362*	0.211	.507**	.460**
	Sig. (2-tailed)	0.707	0.949	0.377	0.986	0.007	0.450	0.303	0.002	0.202	0.070	0.608	0.830	0.199	0.257	0.761	0.005	0.188	0.394	0.041	0.225	0.002	0.006
	N	41	40	40	40	40	40	40	39	39	39	37	37	37	37	37	37	36	36	35	35	35	35
Overall, I feel I'm doing well in this course.	Pearson Correlation	.466**	.359*	.333*	0.309	0.059	0.137	0.276	0.023	0.214	.361*	0.251	.339*	.402*	0.167	.350*	-0.070	0.259	0.263	0.000	.416*	0.252	0.073
	Sig. (2-tailed)	0.003	0.032	0.041	0.059	0.725	0.413	0.098	0.893	0.198	0.020	0.140	0.050	0.018	0.329	0.042	0.694	0.146	0.187	1.000	0.016	0.157	0.682
	N	38	35	38	35	38	38	38	38	35	37	36	34	34	36	34	34	33	34	36	33	35	34

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4: Statistical correlation between questions on working together and perception of learning for computer science students.

APPENDIX C: Non-parametric tests

C.1 Statistical analysis of computer science data

A series of two-tailed Wilcoxon signed-rank test was conducted. The analysis closely mirrored the initial analysis using parametric tests. For example, a Wilcoxon singed-rank test shows that the students enjoyed the game-based lecture significantly more than the regular lecture ($Z = -2.43, p = 0.015$). The tables below illustrate these results for questions regarding students' perception of learning and enjoyment and working together.

Table 3: Students' responses to questions about the lecture styles. All Z values are based on positive ranks.

	Lecture Style	Mean	SD	Z	P Value
It was clear to me what I was supposed to learn in this lecture.	Game-Based	7.87	1.05	-1.94	0.52
	Regular	7.70	1.19		
What we were taught seems to match what we were supposed to learn.	Game-Based	8.02	0.99	-1.70	0.088
	Regular	7.83	1.21		
The lecture was well organized and ran smoothly.	Game-Based	8.15	0.92	-1.35	0.175
	Regular	7.89	1.07		
I could see the relevance of most of what we were taught in this lecture.	Game-Based	8.10	0.90	-1.09	0.272
	Regular	7.86	1.10		
I felt encouraged to rethink my understanding of some aspects of the subject.	Game-Based	7.37	1.39	-1.77	0.076
	Regular	7.13	1.63		
We weren't just given information, we developed it with the instructor and each other.	Game-Based	7.30	1.43	-0.58[3]	0.56
	Regular	7.58	1.33		
I enjoyed this lecture	Game-Based	8.02	1.18	-2.43	0.015
	Regular	7.45	1.66		

Table 4: Working together

	Lecture Style	Mean	SD	Z	P Value
Students supported each other and tried to give help when it was needed.	Game-Based	7.17	1.59	-1.43	0.15
	Regular	6.86	1.67		
Talking with other students helped me to develop my understanding.	Game-Based	6.71	1.91	-1.61	0.10
	Regular	6.41	1.93		
Students' views were valued in this lecture.	Game-Based	7.84	1.32	-.59	0.55
	Regular	7.62	1.37		
I found I could generally work comfortably with other students in this lecture.	Game-Based	6.97	1.95	-1.74	0.08
	Regular	6.48	2.10		

C.2 Spearman's rank-order correlation

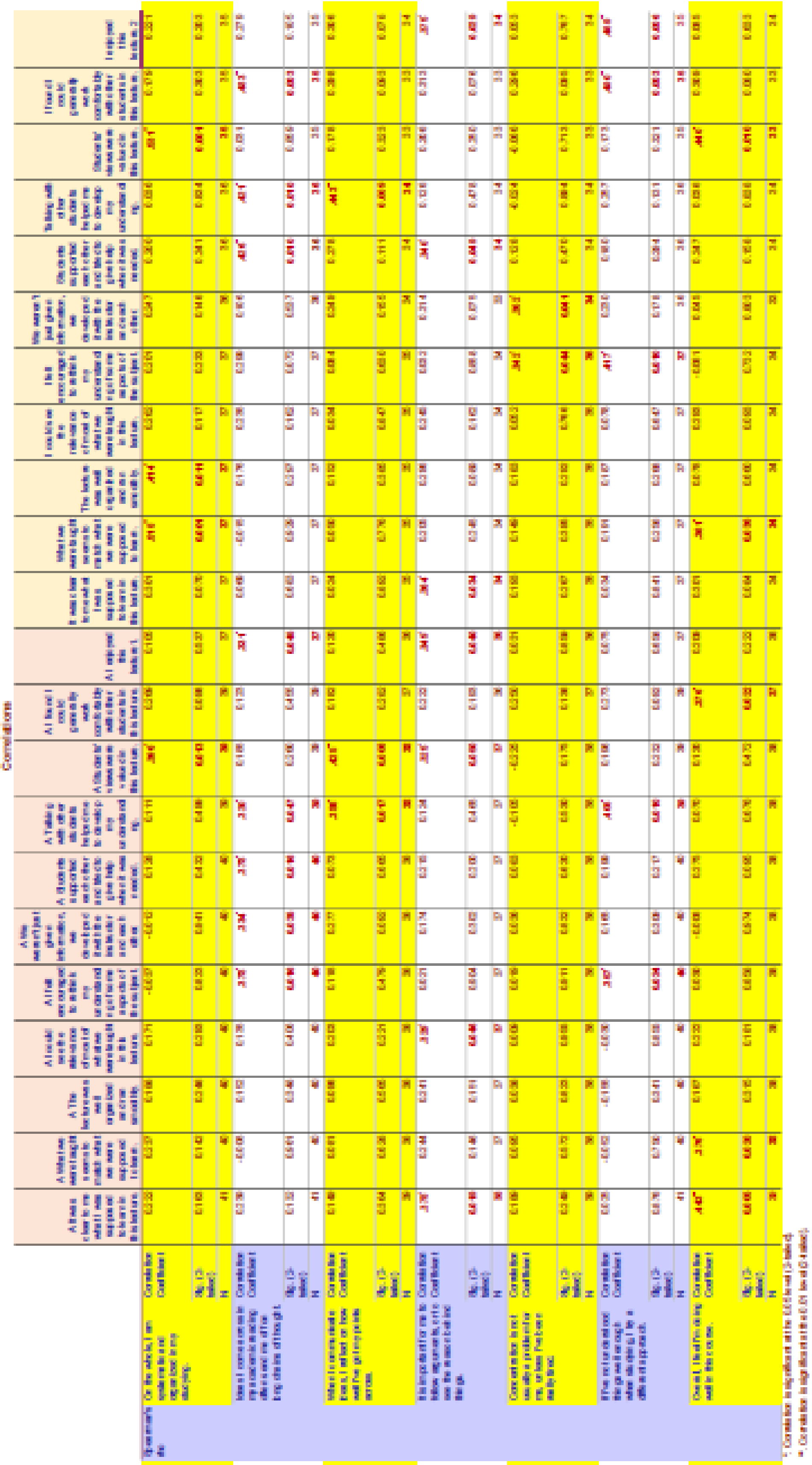

Figure 5: Spearman's rank-order correlation between questions on working together and perceptions of learning.