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Board 329: Investigating the Impact of Context Choice on Learning Experience via Immersive Simulations in an Object-Oriented Programming Course

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Investigating the Impact of Context Choice on Learning Experience via Immersive Simulations in an Object-Oriented Programming Course

Abstract

Researchers have looked into ways to make computer science assignments more engaging, practical, and beneficial to students to improve learning outcomes by increasing student appeal. Offering a pool of assignments and allowing students to choose their preferred assignments is considered as a potential method for improving learning outcomes. In this paper, we investigate the effect of context choice for assignments in an object-oriented programming course that covers various topics such as object-oriented programming concepts, database design and implementation, graphical user interface design, and web application development. Students complete three immersive simulation-based learning (ISBL) modules as course assignments. ISBL modules involve technology-enhanced problem-based learning where the problem context is represented via a three-dimensional (3D), animated discrete-event simulation model that resembles a real-world system or context, in this case, we have three simulated systems/contexts around which ISBL assignments are defined: an airport, a manufacturing system, and a hospital emergency department. The research experiments involve four groups: (1) students with no choice who use the same assigned simulated system for all three ISBL assignments; (2) students with no choice who are given a different simulated system for each ISBL assignment; (3) students who can choose their preferred simulated system at the beginning but cannot change their choice for future assignments; and, (4) students who can choose at the beginning and switch between the three simulated systems for subsequent assignments. Data are collected over multiple semesters and statistical analyses are conducted to compare the four groups in terms of motivation, experiential learning, and self-assessment of learning. We also conduct qualitative assessments in the form of interviews to support and explain our statistical results.

Introduction and Background

Object-oriented programming (OOP) with web applications is one of the fundamental courses in a computer science curriculum. The course typically covers OOP principles and their application, graphical user interface (GUI) design, event handling, server-side programming, database queries, and web-based, net-centric computing. Extensive programming assignments provide an understanding of the entire process of UML class diagram development, application prototyping, database-oriented command line applications, and GUI desktop application development. The topics covered provide many opportunities to incorporate real-life examples to enhance teaching and learning, and consequently, a ripe environment for implementation of Problem-Based Learning (PBL). PBL is a well-known student-centered approach that employs active learning to have students solve complex problems that mimic real-world situations [1]. PBL is shown to improve innovation [2], meta-cognition [3], engagement and meaningfulness [4, 5]. It also promotes design thinking [6] and curriculum integration [7, 8]. PBL encourages students to learn by doing rather than memorizing [9], and is recommended as an effective teaching and learning method in computer science courses [10].

The immersive simulation-based learning (ISBL) modules used in this paper combine the benefits of PBL and immersive simulated environments. Simulated and immersive environments, such as virtual reality (VR), immerse the user in a virtual world with which the user can interact [11]. Several studies have investigated the efficacy of immersive technologies in computer science majors [12]. Immersive technologies enable location-independent learning by providing portable and risk-free learning environments [13]. Furthermore, immersive technologies can positively affect users' attitudes, presenting an effective and efficient learning and training environment, and increasing students' motivation to learn within a virtual environment [12]. The interested reader is referred to [14] for a comprehensive review of immersive virtual environments in higher education, [15] for a bibliometric analysis of the combination of PBL and immersive technologies in engineering education, and [16, 17] for sample applications of ISBL in engineering education.

One of the key challenges in teaching OOP class (and many other courses) is how to keep students motivated [18]. Researchers have looked into the effect of giving students choice in an introductory computer science course [19]. They found that care must be taken when offering options to students as their choice may unintentionally and adversely affect both their learning experience and course performance. Another study investigates how students' choice-making opportunities may be related to student motivation and learner empowerment [20]. They found that teachers who communicate a mix of policy styles (e.g., voluntary attendance & no assignment choices or mandatory attendance & assignment choices) may be obstructing individual initiations to participate in class and decrease positive views of value toward the class among students. Several other researchers also investigated ways to increase student motivation by giving students a choice in their class assignments [21, 22, 23]. Overall, there is a mixed set of findings in the literature on positive and negative effects of giving students some level of choice related to their assignments. This necessitates exploring the effect of choice for any new teaching and learning method such as ISBL.

Motivated by the above, this paper investigates the effect of providing students with the choice to select the simulated system (i.e., context) associated with their ISBL assignments. In other words, there is a pool of ISBL assignments that involve the same learning objectives and tasks but are applied to different contexts, namely airport, manufacturing, and healthcare systems. In the following sections, we will describe the various components of an ISBL module and its supporting pedagogical and psychological theories, and the sample ISBL modules used in our experiments with an undergraduate OOP course. The experimental design is then described, followed by the results of our quantitative assessments, statistical comparisons, and a set of qualitative assessments based on user interviews. Lastly, we will discuss the lessons learned and future research opportunities.

Immersive Simulation-Based Learning (ISBL) Modules

The proposed ISBL modules are specified by two main components:

(a) A 3D animated, VR-compatible discrete event simulation model that mimics the dynamics of a real system and its entities (e.g., people, products, raw materials that are processed, assembled, manufactured, stored, transferred, or transported depending on the simulated context). The simulation provides the *context* for technology-enhanced PBL. The simulation models in our proposed ISBL modules can be used on any standard 2D display or via a VR headset for a more immersive experience.

(b) A PBL learning activity defined around the simulated system and inspired by real-world situations that learners may encounter in a professional setting or future workplace.

Many of the pedagogical and psychological theories that support PBL also apply to ISBL or enhanced as a result of integration with a simulated environment. For example:

- ISBL promotes long-term development of critical thinking and problem-solving skills by (a) activating relevant prior knowledge; (b) providing a contextually enriched environment (via immersive simulations); and (c) encouraging learners to elaborate on their knowledge to solve a real-world inspired problem. These are the three guiding principles of the Information Processing Approach to Learning Theory [24].
- In traditional course assignments, the underlying context and an environment to interact with are often missing. The immersive simulations in ISBL aim to fill this void. ISBL enables knowledge to be constructed through interactions with the simulated environment and indexed by relevant contexts. These characteristics of ISBL are consistent with Constructivism Theory [25], according to which, learners construct their mental models of the real world through cognitive and interpretive activities.
- ISBL allows learners to include their perspectives and take greater ownership of their learning. This makes ISBL align with the Self-determination Theory [26] by promoting autonomous motivators, as opposed to traditional approaches, which are primarily based on controlled motivators such as rewards and punishments (e.g., passing or failing a test). Such controlled motivators often lead to superficial learning and can cause a sense of pressure and anxiety in students.
- ISBL problems closely resemble real-world situations, hence are especially appropriate for professional and continuing education. ISBL offers a self-directed, problem-centered learning experience that draws from prior work experiences and integrates into the professional learner's daily life. These features of ISBL support some of the key components of the Adult Learning Theory [27].

ISBL has several other advantages as well. For example, students conduct virtual site visits (by navigating in the simulation) to observe and collect data (as opposed to visiting a real-world facility in person). Virtual site visits alleviate several critical barriers in current STEM education and workforce development, namely: (a) geographical barriers that prevent contextualized learning, e.g., lack of proximity to industries or geographically spread formal/informal learners in online education; (b) corporations' reluctance to provide access to their facilities and data; and/or, (c) logistics/schedule constraints that prohibit real-world site visits (e.g., conflict with other classes or work commitments for professional students).

The immersive simulations for the ISBL modules investigated in this paper are created using the Simio simulation software [28]. The software is free for educational use and compatible with VR, giving learners the option of viewing the simulated environment on a 2D display (low-immersion mode) or a VR headset (high-immersion mode). The following section describes the integration of several ISBL modules in an undergraduate OOP class. For a complete list of ISBL modules developed for other STEM courses/disciplines as part of our overarching educational project that this paper stems from, see our project website at `https://sites.psu.edu/immersivesimulationpbl`.

ISBL Implementation in an Undergraduate Computer Science Course

The undergraduate Computer Science program at Penn State University - Abington College offers a second-year course in object-oriented programming (OOP). This is a required course for the program and an elective course for other engineering majors. The course is offered in fall and spring semesters. The course sections used in this study were offered in Spring 2021, Fall 2021, Spring 2022, and Fall 2022. The high-level objectives of the course are designed so that, upon successful completion, the student will be able to:

- develop computer programs in an object-oriented language (Java),
- write code to interface databases using Java,
- create graphical user interfaces using Java,
- understand web-based OOP and design including the concepts of net-centric computing,
- understand interface prototyping, program design, implementation of both client and server programs, unit testing, and documentation.

The class is structured to be taught either online or in person and includes video-recorded lectures, online quizzes for each lecture, homework assignments, a class project, and two exams. Three ISBL assignments are integrated into the course and students are given two weeks to complete each ISBL module. Each ISBL assignment is accompanied by a document that describes the system at hand, lists the learning objects, and the problem(s) to be solved. Each ISBL module is also accompanied by a 3D animated, VR-compatible simulation model that serves as the context, and the students are asked to treat the simulated system as the "real-world system". For each ISBL assignment, there are three versions based on the type of system/context: an airport terminal, a manufacturing assembly plant, and a hospital emergency department. Figure 1 provides screenshots of these simulated systems.

For the sake of conciseness, we describe only one of the ISBL modules here and refer the interested reader to our project website at `https://sites.psu.edu/immersivesimulationpbl` where all ISBL modules developed as part of our ongoing project are shared publicly. The airport terminal has areas with several self-check-in kiosks, a check-in counter with agents, an ID/boarding pass checkpoint station, two advanced imaging technology (AIT) stations for scanning passengers and their luggage, and two gates in the boarding area each having its own seating/waiting area where passengers wait before boarding on their flight. Flights board and leave according to a stochastic process specified in the simulation model.

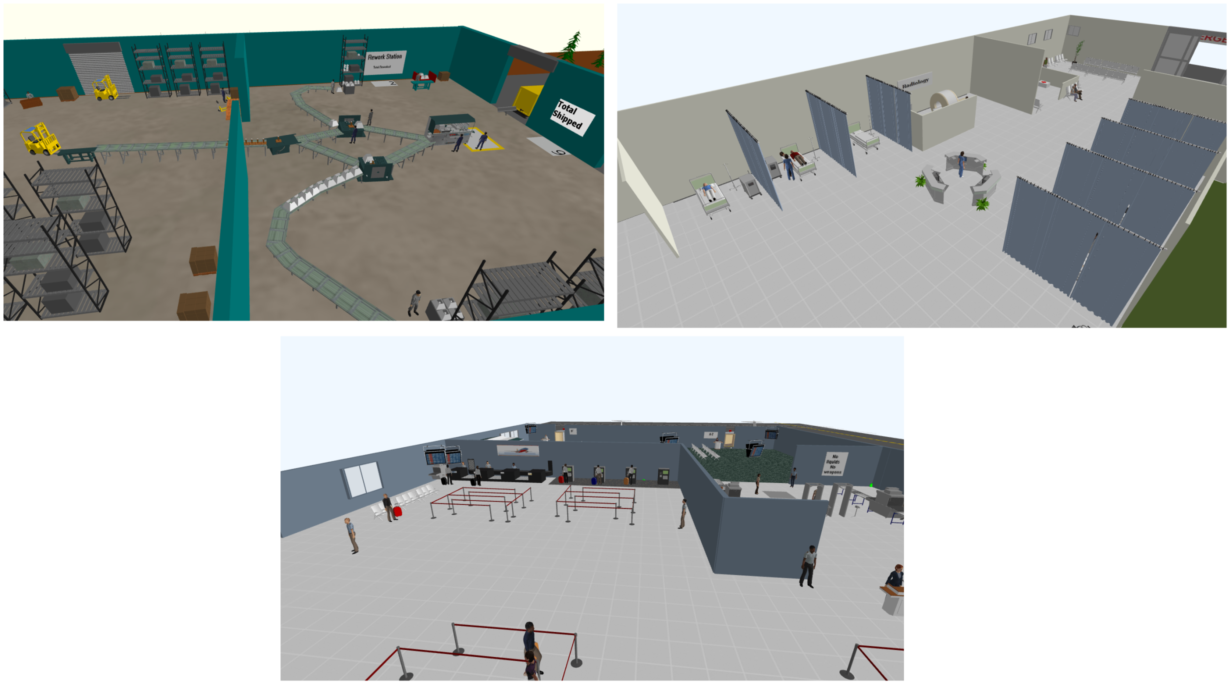

Figure 1: Three contexts used in the ISBL modules: a manufacturing assembly plant, a hospital emergency department, and an airport terminal

The problem statement can be summarized as follows. The construction of a new airport terminal in a small town has recently been completed. The student is hired as a software engineer to develop an information system using an object-oriented programming language. The student needs to observe the airport operation, identify the classes/methods/attributes, develop a pseudo-code of the system, and create a UML class diagram of the system. As for the learning objectives, after successful completion of this ISBL module, the student will be able to:

1. Identify relevant classes and their attributes, methods, and relationships by observing a system.
2. Develop a pseudo-code based on the identified classes, attributes, methods, and relationships.
3. Create a UML Class diagram based on the pseudo-code.

Research and Experiment Design

Figure 2 summarizes the general design of our experiments. IRB approval was obtained prior to the experiments and data collection. As mentioned previously, three ISBL assignments are integrated into the course and, for each ISBL assignment, there are three versions based on the type of system/context: an airport terminal, a manufacturing assembly plant, and a hospital emergency department. The three versions of each ISBL assignment are identical in terms of learning objectives, difficulty, workload, and tasks to be completed. Therefore, the only difference is in the type of system modeled in the accompanied simulation.

We compare four levels of choice by randomly assigning each student to one of four groups:

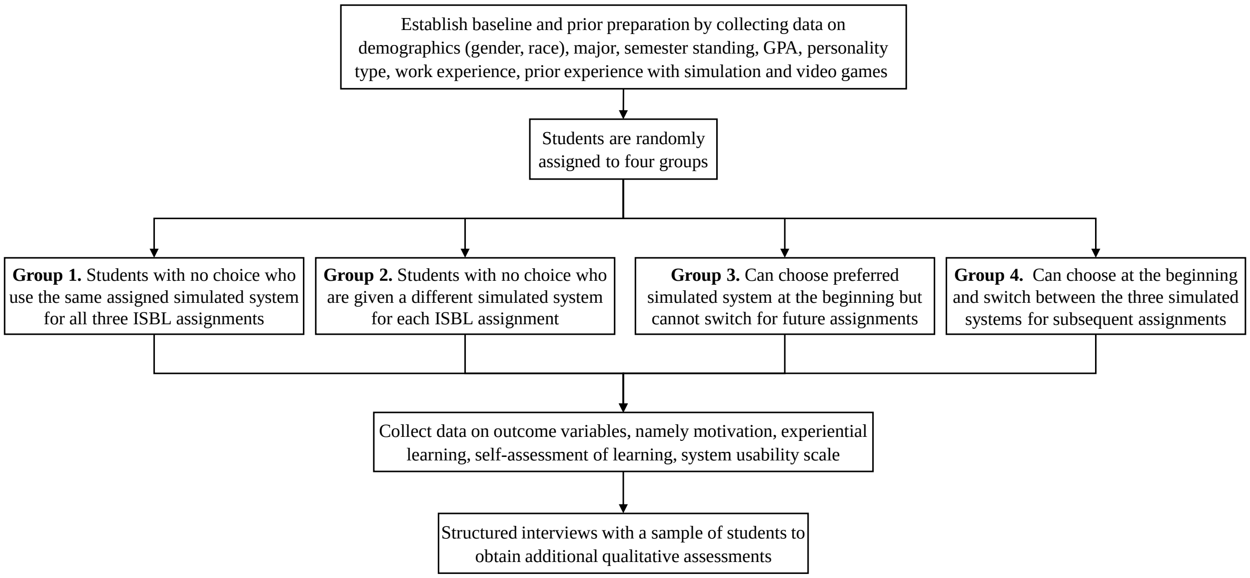

Figure 2: General design of the assessment experiments

(1) students with no choice who use the same assigned simulated system for all three ISBL assignments; (2) students with no choice who are given a different simulated system for each ISBL assignment; (3) students who can choose their preferred simulated system at the beginning but cannot change their choice for future assignments; and, (4) students who can choose at the beginning and switch between the three simulated systems for subsequent assignments.

We used the following instruments/methods for data collection:

- Demographics survey: Collects data about the subject's age, gender, race, grade point average (GPA), grade in a prerequisite course, major, semester standing, work experience, and prior experience with computer simulation and video games in general.
- Big Five Inventory (BFI-10) Personality Test: This is a 10-item version of the Big Five Inventory questionnaire (a.k.a., the Five Factor model of personality). The instrument identifies the following personality traits: extroversion, agreeableness, conscientiousness, neuroticism, and openness to experiences.
- Reduced Instructional Materials Motivation Scale (RIMMS): This is a 12-item questionnaire to assess the level of student motivation as measured by four factors: attention, relevance, confidence, and satisfaction. Each factor has 3 items in the questionnaire.
- Experiential Learning Survey: Experiential or experience-based learning generally refers to settings where students participate in activities that enable learning by doing. This is a 12-item questionnaire that evaluates the student's perception of experience-based educational instruction as established in the experiential learning theory [29]. Here, we focus on two of the constructs measured by this instrument, namely how the *environment* influenced learning, and how useful the learning experience was in terms of *utility* in future endeavors. It is worth noting that the original experiential learning instrument includes two other constructs,

namely *active learning* and *relevance*, which were excluded in our implementation of this instrument due to their overlap with the constructs measured by the RIMMS survey. More specifically, *relevance* is measured by the RIMMS survey, and *active learning*, which refers to the student's level of engagement with the learning material, is directly related to the *Attention* construct in RIMMS.

- Self-assessment based on Bloom's Taxonomy of learning objectives: This survey is designed to assess students' self-perceived knowledge related to a set of topics [30]. In our study, students are asked to rank their perceived knowledge of various OOP-related topics by selecting one of six levels that they think best describes their level of learning. For each topic, the six levels that the respondent can choose from are adapted from Bloom's taxonomy and are as follows: (1) I can *remember* related concepts/steps; (2) I can *explain* related concepts/steps; (3) I can *apply* this topic/method to a different problem/situation; (4) I can *analyze* the meaning of the related concepts/steps in the context and why they are there; (5) I can *evaluate* and ensure the correctness of the use of the related concepts/steps; (6) I can *use* this topic/method in problem-solving without an example.
- System Usability Scale (SUS) survey: This survey is used to assess the user's subjective rating of a product's usability. The survey measures four types of user experience factors: involvement, immersion, visual fidelity, and interface quality [31].
- Student interviews: Interviews are conducted with a sample of participating students to obtain additional qualitative assessment of their experience with the ISBL modules and level of choice. Interviews incorporate ethnographic methods and include six structured questions designed to fit into a twenty-minute interview format [32]. The questions cover what students like best about the ISBL modules and level of choice related to the simulated system, suggestions for improvement, navigation experience, impact on learning, recommendations for future users, and an "Anything else to add" question. Interview notes are analyzed using qualitative data analysis techniques from Grounded Theory to produce a set of themes across student experiences [33].

Student Population

Table 1 shows the gender composition of the student participants. As shown in Figure 3, the majority of the students in ever group are in computer science majors with a few students being from other disciplines. The majority of the students in every group have no previous work experience as shown in Table 2. Figure 4 provides the semester standing of students. We also asked about the level of experience with computer simulation (Table 3) and computer games (Table 4). Figure 5 compares the GPA of students in the four groups. There was no significant statistical difference between the four groups in terms of their median GPA (H_0 : Population medians are equal, the p-value is 0.826 using a Kruskal Wallis test). There was no significant statistical difference between the four groups in terms of each BFI-10 construct or the overall BFI-10 score (H_0 : Population medians are equal, all p-values significantly greater than the cutoff point using a Kruskal Wallis test). Based on the above comparisons, the groups can be considered homogeneous and comparable.

Table 1: Gender composition per group

	Male	Female	Other
Group 1 (No choice, same context for all assignments)	80.77%	19.23%	0%
Group 2 (No choice, different context for each assignment)	88.89%	11.11%	0%
Group 3 (Choice at the beginning, no change afterwards)	92.00%	8.00%	0%
Group 4 (Choice for each assignment)	75.00%	25.00%	0%

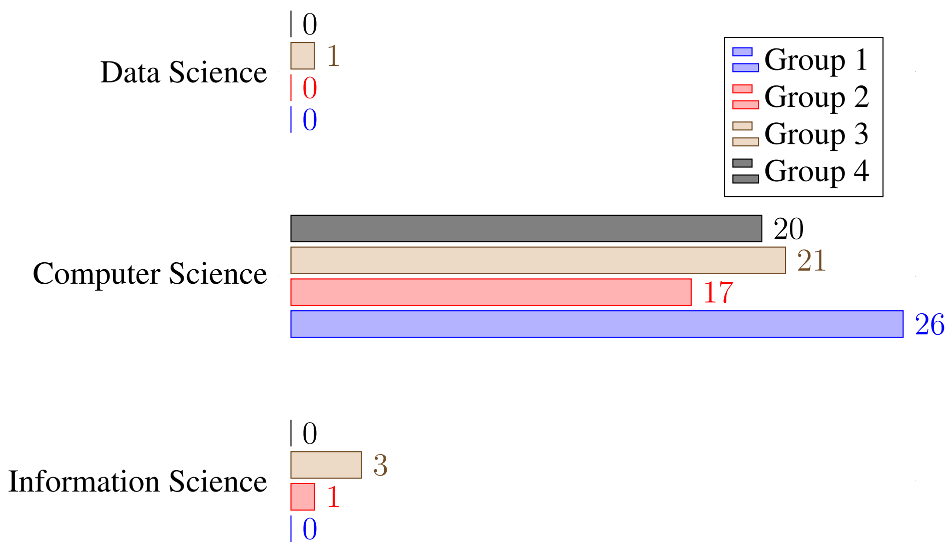

Figure 3: Number of students by major

Research Hypotheses

All course sections from which we collected data used the same instructional material offered by the same instructor. Since the only difference between the four groups was the level of choice offered for the ISBL assignments, it is hypothesized that any statistical group differences detected can be attributed to the level of choice students were given for the type of simulated system associated with their ISBL modules. We use our experiments to investigate the following hypotheses:

- **Hypothesis 1:** In ISBL, the level of choice related to the simulated system/context has a statistically significant effect on students' motivation as measured by the RIMMS instrument.
- **Hypothesis 2:** In ISBL, the level of choice related to the simulated system/context has a statistically significant effect on students' experiential learning.

Table 2: Percentage of students broken down by previous work experience

Group	Has Work Experience	No Work Experience
Group 1	11.54%	88.46%
Group 2	5.56%	94.44%
Group 3	16.00%	84.00%
Group 4	5.00%	95.00%

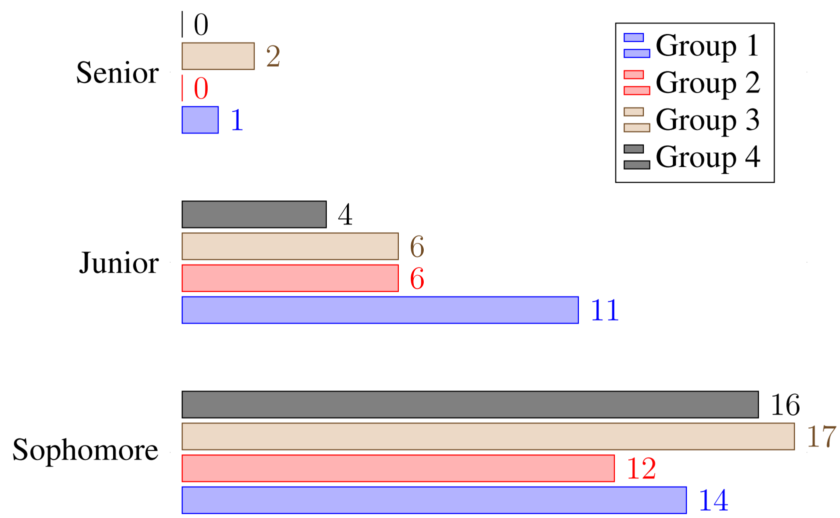

Figure 4: Number of students by their semester standing

Table 3: Percentage of students broken down by experience with computer simulation

Group	No Experience	Some Experience	Expert
Group 1	30.77%	57.70%	11.53%
Group 2	33.33%	66.67%	0.00%
Group 3	16.00%	84.00%	0.00%
Group 4	35.00%	65.00%	0.00%

- **Hypothesis 3:** In ISBL, the level of choice related to the simulated system/context has a statistically significant effect on students' self-assessment of learning based on Bloom's Taxonomy of learning objectives.
- **Hypothesis 4:** The level of choice related to the simulated system/context has a statistically significant effect on students' performance as measured by their average grade for the three ISBL assignments.

We also investigated the usability of the ISBL modules. The scores from the usability survey will be used to improve the design of future ISBL modules developed as part of our overarching STEM educational research project. For the sake of conciseness, we do not provide the usability survey results in this paper.

Table 4: Percentage of students broken down by experience with computer games

Group	No Experience	Some Experience	Expert
Group 1	0.00%	57.69%	42.31%
Group 2	0.00%	27.78%	72.22%
Group 3	0.00%	60.00%	40.00%
Group 4	15.00%	45.00%	40.00%

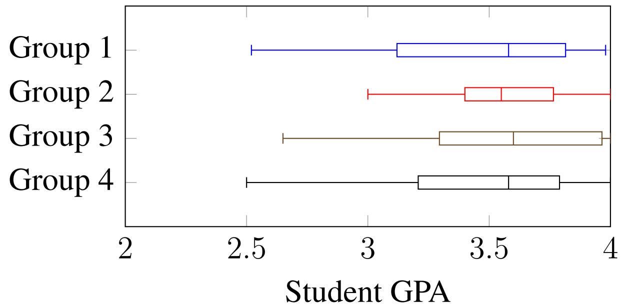

Figure 5: Box plot for student GPAs

Quantitative Assessments: Statistical Comparisons and Results

We perform a series of Kruskal-Wallis tests to statistically compare the four groups, i.e., four levels of context choice in ISBL. Kruskal-Wallis is a nonparametric method for testing whether samples are originated from the same distribution. All statistical tests in this paper are performed at a 5% significance level using the Minitab statistical software. For the sake of conciseness, we only present the results for constructs where a significant statistical difference is detected.

In Figure 6, we test the null hypothesis that the four distributions have the same median in terms of their overall RIMMS score and find a significant statistical difference between the four groups. Looking at the mean rank and Z-value statistics, we observe that the observations in Group 1 (students with no choice who use the same assigned simulated system for all three ISBL assignments) have the highest average rank and that Group 1's average rank is greater than the overall average rank of all observations as indicated by the Z-value.

Descriptive Statistics

Experiment	N	Median	Mean Rank	Z-Value
Group 1	26	46.5	55.2	2.40
Group 2	18	36.5	33.2	-2.17
Group 3	25	39.0	44.9	-0.03
Group 4	20	40.5	42.5	-0.49
Overall	89		45.0	

Test

Null hypothesis H_0: All medians are equal
Alternative hypothesis H_1: At least one median is different

Method	DF	H-Value	P-Value
Not adjusted for ties	3	8.01	0.046
Adjusted for ties	3	8.02	0.046

Figure 6: Minitab results for Kruskall-Wallis test for RIMMS overall score

In Figure 7, we test whether the four distributions have the same median in terms of the score for RIMMS' *attention* construct and find a significant statistical difference between the four groups. Based on the mean rank and Z-value statistics, the observations in Group 1 (students with no choice who use the same assigned simulated system for all three ISBL assignments) have the highest average rank. Also, Group 1's average rank is greater than the overall average rank of all observations as indicated by the Z-value. The positive Z-value for Group 3 indicates that students who can choose their preferred simulated system at the beginning but cannot change their choice in

Descriptive Statistics

Experiment	N	Median	Mean Rank	Z-Value
Group 1	26	12	55.4	2.45
Group 2	18	9	35.1	-1.81
Group 3	25	9	46.0	0.24
Group 4	20	9	39.0	-1.17
Overall	89		45.0	

Test

Null hypothesis	H_0: All medians are equal
Alternative hypothesis	H_1: At least one median is different

Method	DF	H-Value	P-Value
Not adjusted for ties	3	7.96	0.047
Adjusted for ties	3	8.10	0.044

Figure 7: Minitab results for Kruskall-Wallis test for RIMMS attention construct

Descriptive Statistics

Experiment	N	Median	Mean Rank	Z-Value
Group 1	26	11.5	54.7	2.27
Group 2	18	10.0	31.0	-2.57
Group 3	25	11.0	45.0	0.01
Group 4	20	11.0	44.9	-0.01
Overall	89		45.0	

Test

Null hypothesis	H_0: All medians are equal
Alternative hypothesis	H_1: At least one median is different

Method	DF	H-Value	P-Value
Not adjusted for ties	3	8.92	0.030
Adjusted for ties	3	9.09	0.028

Figure 8: Minitab results for Kruskall-Wallis test for RIMMS confidence construct

subsequent ISBL assignments also report a higher average rank than the overall average rank of all students. We observe similar results for RIMMS' *confidence* construct as shown in Figure 8.

We also compared the four groups in terms of experiential learning for two constructs *Environment* and *Utility*. We started by the Anderson-Darling normality test and found that the *Environment* data meets the normality condition (p-value = 0.080), hence we performed one-way ANOVA (null hypothesis: all means are equal) and found no statistically significant difference between the four groups in terms of their *Environment* score. The *Utility* data did not pass the normalilty test (p-value <0.005), hence we performed the Kruskal-Wallis test and found no statistically significant difference between the four groups in terms of their median *Utility* score.

We tested the self-assessment average scores using the Anderson-Darling normality test, which did not pass the test (p-value <0.005), hence we used the Kruskal-Wallis test and found no statistically significant difference between the four groups in terms of self-assessment scores (the p-value is 0.854). In addition, Figure 9 compares the four groups in terms of the students' average grade for the three ISBL assignments. The Kruskal-Wallis test showed no statistical difference between the four groups (p-value = 0.802).

In summary, the statistical results support our first research hypothesis that, in ISBL, the level of choice related to the simulated system/context has a statistically significant effect on students' motivation, and in particular, on their overall RIMMS socre as well as their scores for RIMMS *atten-*

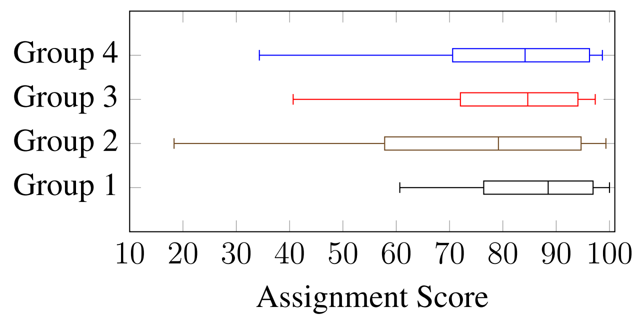

Figure 9: Box plots of average grade for the three ISBL assignments

tion and *confidence* constructs. On the other hand, the results do not support research hypotheses 2, 3, and 4. In other words, we did not find statistical evidence to support that the level of choice related to the simulated system/context affects students' experiential learning, self-assessment of learning, or their performance (grade) in ISBL assignments. In the following section, we discuss the results of our *qualitative* assessments in the form of structured interviews to provide additional insights about our statistical results.

Qualitative Assessment

Interviews were conducted with a group of students from the classes to obtain a qualitative assessment of student experiences with the ISBL modules. Interviews were influenced by ethnographic methods and followed a set of six structured questions designed to fit into a twenty-minute interview format [32]. Questions covered a range of topics related to their experience using the modules but this analysis is focused on their experience with regard to the choice of which simulated system (context) to use for their assignments. Students were provided with a variety of experimental conditions including no choice, some choice, and full choice regarding the selection of ISBL modules. Interview notes were taken and analyzed using qualitative data analysis techniques from Grounded Theory to produce a set of themes across student experiences [33].

Qualitative interviews about the ISBL module experience were conducted with 32 students. All but three students preferred having a choice of their modules. Three themes emerged from the data related to choice. Theme one related to the time and effort required to learn a module to use with an assignment. Many students appreciated the freedom to choose a module to use but then preferred to stick with that module rather than learn a new one to complete the rest of the assignments. One student commented, "I would not have wanted to switch after learning one environment." Similarly, another student commented, "I would like to stick with the airport terminal module as it would have been tough to figure out different environments." This explains our statistical findings on Group 1 (No choice, same context for all assignments) and Group 3 (Choice at the beginning, no change afterwards) being superior in terms of motivation-related constructs as discussed in the previous section.

Theme two, related to choice for type of simulated system, was the decision to choose an ISBL module that would be related to a future industry/career choice. Some students had a tendency to choose modules that seemed to match their interests. For example, one student commented, "Airport terminal, I picked this one. I was interested in it for future career. I liked being able to pick. I got to see all three, and if we were assigned one, it would not have been related to my career interests." Another student commented, "I chose manufacturing because I had some experience working in a warehouse as an Amazon associate. I thought it was cool that there was a VR simulation of a warehouse." Another commented, "I chose manufacturing because I thought I might go into that type of work."

Theme three, related to project choice, was a desire to explore modules to determine which worked best for them in terms of interest and usability. One student who did not get a choice commented, "I wish we had the opportunity to pick and choose, some others sound interesting." Similarly, another commented, "I would have liked to work with the hospital module because it looked like more fun." A third student commented, "The first time you don't realize what (module) is going to work so it is nice to have a do-over." Another student commented, "I looked at others, but I was more interested in the airport. Being given a choice made me realize that it doesn't have to be boring. I could move to another if I wanted."

In sum, most students preferred having a choice of ISBL module but many wanted to stick with one once they learned how to operate it to complete assignments. Some students also preferred to choose a module that matched a future career choice. Students also preferred to explore modules and find ones that seem interesting and works best for them to complete assignments.

Conclusions

In this paper, we investigated the effect of allowing the students to choose the simulated system/context in Immersive Simulation-Based Learning (ISBL) assignments. The research experiments involve four groups of undergraduate students taking an object-oriented programming course: (1) students with no choice who use the same assigned simulated system for all three ISBL assignments; (2) students with no choice who are given a different simulated system for each ISBL assignment; (3) students who can choose their preferred simulated system at the beginning but cannot change their choice for future assignments; and, (4) students who can choose at the beginning and switch between the three simulated systems for subsequent assignments. The statistical results show that context choice has a statistically significant effect on students' motivation, with groups 1 and 3 reporting the highest motivation levels. On the other hand, we did not find statistical evidence to support that context choice affects experiential learning, self-assessment of learning, or students' performance or grade in ISBL assignments. Our qualitative analysis of structured interviews with student participants also corroborate with the statistical findings.

Based on our quantitative and qualitative results, as well as the somewhat conflicting findings in the literature on the effect of "choice", an important area for future research is to explore the relationship between student characteristics (e.g., personality types, demographics, etc.) and perceived pressure as a result of having to choose from multiple assignment options. In our experiment, some students felt they had to read all assignment options to make the "right decision" meaning the assignment choice with less difficulty and workload, even though they were told all choices had similar workload and difficulty. Understanding what groups of students feel stressed when choosing from multiple options can help design strategies to minimize such negative effects of assignment choice.

We hope that the findings presented in this paper help educators with proper implementation of ISBL and decision-making related to offering context choice to their students.

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