Assessing Comprehension With Student-Developed Construction Games

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Abstract

To train the next generation of construction professionals, we must address teaching approaches so students can have the best opportunity to excel on multidisciplinary teams.
Faculty and researchers are piloting an assessment method for an introductory construction class entitled Building Construction Materials, Methods and Equipment. The assessment employs student-developed games to achieve course learning objectives, including mastery of 140 construction-oriented terms, and has the potential to replace the previously assigned photo glossary project in which students summarized how these terms were relevant to real-world construction projects. The team-based game approach, conducted in three stages over three class days, presents an assessment of the games developed in this course via evidence of Bloom's levels of intellectual behavior in game design and accuracy in connecting course concepts to one another [1]. Preliminary results show that students' reaction to learning objective assessment via game-design days is overwhelmingly positive; students have met the game design material and activities with enthusiasm and have already shown excitement in demonstrating mastery of concepts through the team-based, active and experiential learning game design approach. All classroom game development instructions developed during this project will be made available to download and use in classes at other universities.

Introduction

Current undergraduate construction curricula is faced with several challenges including, but not limited to, providing contextualized classroom and field experiences, teaching students with diverse capabilities, refining students' effective communication abilities and improving assessments of course learning outcomes. Addressing current challenges requires construction educators to increase their use of pedagogies that enhance students' education. The National Research Council (NRC) notes several challenges to effective undergraduate education in science, technology, engineering, and mathematics (STEM) disciplines, including providing engaging laboratory, classroom and field experiences; teaching large numbers of students from diverse backgrounds; improving assessment of learning outcomes; and informing science faculty about research on effective teaching [2-4]. In addition, research suggests that team based projects can also enhance student learning in STEM fields since it promotes active and collaborative learning while simultaneously promoting individual accountability, personal responsibility, and communication skills [5].

Addressing current challenges requires educators to increase their use of approaches that enhance learning in the STEM classrooms. Experiential and active learning are two well-known pedagogies that can benefit from a team-based approach. Experiential learning engages students in a real, rather than abstract, experience [6, 7]. Active learning enhances students' ability to exercise lifelong learning by placing the learning responsibility on the learners themselves [8]. Project-based learning, using a project to simulate student learning, is well-cited as an effective pedagogy for construction education [9-11]. Adopting these pedagogies into construction curricula allows educators to address students' needs via exposure to and interaction with real-

world multidisciplinary problems that require multiple levels of communication with many stakeholders.

Games and game-based learning have been used in many classrooms, from K-12 to undergraduate, to engage students with different learning styles and to excite students about course material. Digital games give students the opportunity to experience technology-enabled learning and enable, in some instances, multi-player, strategic thinking [12]. Board games afford students an in-person interaction, requiring a student to make decisions in the presence of competitors, and do not necessary require a computer or skills to handle the game commands [13]. Game-based learning is well-documented as a method to engage and motivate students with course material in order to improve student learning outcomes [14].

This paper presents a pilot study to assess student learning (i.e. cognitive outcomes) and student experiences (i.e. affective outcomes) of student-developed games in a 56-person freshman through senior level introductory construction class at Arizona State University (CON 252) entitled Building Construction Materials, Methods and Equipment. One of the merits of exposing students to creative game design in the classroom is that it asks students to begin thinking critically about the content that they should have learned. In addition, the game framework asks students to think about their educational experience in a new way; as the instructor.

The ultimate goals of this student-centric game-design experience are to: 1) expand student experience/affective outcomes through exposure to experiential learning and 2) engage students with a new form of assessment through game design with the aim of enhancing student learning/cognitive outcomes. This paper discusses the development and value in understanding student perceptions of game design from the incorporation of chosen course concepts as gauged on three levels: student peer-peer level, the instructor level and student personal level with the use of reflective post-activity questions. These questions examine the value of the active and experiential activities employed in the undergraduate introduction to construction classroom.

Methods

Student-developed games were designed and played over three game days, referred to as Game Day 1, 2, and 3, within the Building Construction Materials Methods, and Equipment course. The assessment of the student games was conducted via three methods, a student peer-to-peer feedback questionnaire, an instructor assessment questionnaire and a student self-reflection journal entry. The game days and game evaluation methods are described below.

Students were divided into groups of 4-6 people to split the 56-person classroom into 10 total game-design teams. Students were introduced to the game-design activity after completing 7 weeks of their 15-week semester. Game Day 1 consisted of i) introduction to game design by playing a non-construction game, ii) lecture and discussion about game elements and learning objectives, and iii) a brainstorming period for students to develop their construction game idea. Students played the Nano Around the World game, available for free download from the Nanoscale Informal Science Education (NISE) Network at http://www.nisenet.org/catalog/programs/nano_around_world, a card game designed to enable the discussion of nano technology and impact. Despite being unrelated to their field of study, the

Nano Around the World game gave students some starting framework that the instructor built upon with a lecture and discussion about the clarity of game instructions, the game pieces necessary to play the game, game scoring, and overall goals/learning objectives of the game. Following the lecture and discussion, students were given time to brainstorm a game idea within their team. During the brainstorming period, students were told they could think of a game that already existed and modify it to fit their learning objectives or they could create a brand new game from scratch. At the end of Game Day 1, a representative from each group of students presented their game idea to their classmates in an effort to increase the student interaction and exposure to different game ideas and different learning objectives. Students were charged with working on their game ideas and designs in their own groups for the next 6 weeks. A budget of $50 was available to each group for purposes of making their game playable, including the purchase of any supplies necessary to conduct game play, which could include the purchase of an existing game that the students intended to modify or supplies necessary to manufacture a new game form scratch. Students were given the deadline of Game Day 2 to bring in a working game, which consisted of documented course learning objectives, a game board, game pieces, instructions for game play and anything else necessary for the game to be playable by other students.

Game Day 2 was held in week 13 after students had completed an additional 6 weeks of the course and were approaching the end of course material, during which they were applying course concepts to their game design. During Game Day 2 in class, students were asked to pair up with another game-design team and trade games. Students played the other team's game while the designers watched, allowing designers to evaluate the effectiveness of their game and obtain feedback from peers on the game design and underlying learning objectives. At the end of Game Day 2, students were asked to analyze their peer's game design through peer-review feedback questionnaire (Table 1) that was turned in to the instructor. Students were tasked with revising their game according to feedback from their peers over the next week to prepare for Game Day 3.

Table 1: Game Evaluation Method A: Peer Feedback Post-Game Day 2.

Peer Feedback Post-Game Day 2 Questions	**Possible Responses**
1. Name of game you are playing:	Open-ended
2. The instructions for this game were easy to understand.	Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree
3. This game applied course concepts accurately.	Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree
4. What are the weaknesses of this game?	Instructions, Scoring of game, Board/game piece design, Application of course concepts for game play, Other (fill in blank)
5. What are the strengths of this game?	Instructions, Scoring of game, Board/game piece design, Application of course concepts for game play, Other (fill in blank)
6. Please provide recommendations to the game creators to improve this game:	Open-ended

Game Day 3 was conducted during week 14 of the 15-week course. During Game Day 3 students traded their final, working games in class and played the games to demonstrate mastery of the course learning objectives and terms. At the end of Game Day 3, students were asked to analyze their peer's game design through a peer-review questionnaire (Table 2) that was turned into the instructor. Students also turned in their games to the instructor at the end of Game Day 3 to enable the instructor to grade the assignment. The game designs were evaluated for effectiveness of incorporating course concepts into the learning objectives and overall game design (Table 3). Students were given a final assignment of a self-reflection journal entry to document the game-design day process as well as relevancy and recommendations for use in future semesters of this course (Table 4).

Table 2: Game Evaluation Method A: Peer-Evaluation Post-Game Day.

Peer-evaluation Post-Game Day 3 Questions	**Possible Responses**
1. Name of game you are playing:	Open-ended
2. After improvements were made, the instructions for this game were easy to understand.	Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree
3. After improvements were made, this game applied course concepts accurately.	Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree
4. What are the weaknesses of this game?	Instructions, Scoring of game, Board/game piece design, Application of course concepts for game play, Other (fill in blank)
5. What are the strengths of this game?	Instructions, Scoring of game, Board/game piece design, Application of course concepts for game play, Other (fill in blank)
6. This game helped me increase and/or practice applying my knowledge of course concepts.	Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree
7. I would recommend this game to other students in future sections of this course.	Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

Table 3: Game Evaluation Method B: Instructor Assessment.

Instructor Assessment Questions	Possible Responses
1. Name of game:	Open-ended
2. What learning objectives did game creators choose for this game?	Open-ended
3. Where the learning objectives accurately incorporated into game play? Score 1-5, with 5 being optimal score.	High Inaccuracy (1), Inaccuracy (2), Neutral (3), Accuracy (4), High Accuracy (5)
4. What Bloom's Level of Intellectual Behavior [1] is evident in this game?	Remembering, Understanding, Applying, Analyzing, Evaluating, Creating
5. This game's design was professional (i.e. resembled a purchasable game) and effective (i.e. resembled a playable game).	Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

Table 4. Game Evaluation Method C: Self-Reflection Journal Entry.

Self-Reflection Journal Entry Questions	Possible Responses
1. How do you envision creating and playing games with the CON 252 course content impacting your future career?	Open-ended
2. What did you learn from the experience of creating a game using the course learning objectives and applicable terms?	Open-ended
3. Do you think the game development activity should be included in CON 252 next semester? Why or why not?	Open-ended

Results and Discussion

The results from the three game days are presented in three game analysis sections, including the student peer-to-peer evaluation questionnaires, the instructor assessment questionnaires and the student self-reflection journal entries. Figures 1-5 depict the results from the student peer-to-peer evaluation questionnaire administered at the end of Game Day 2 (93% response rate) and at the end of Game Day 3 (73% response rate). Figures 6-8 depict the results from the instructor assessment of the games at the end of the semester. A total of 10 student-developed games were created during this pilot study.

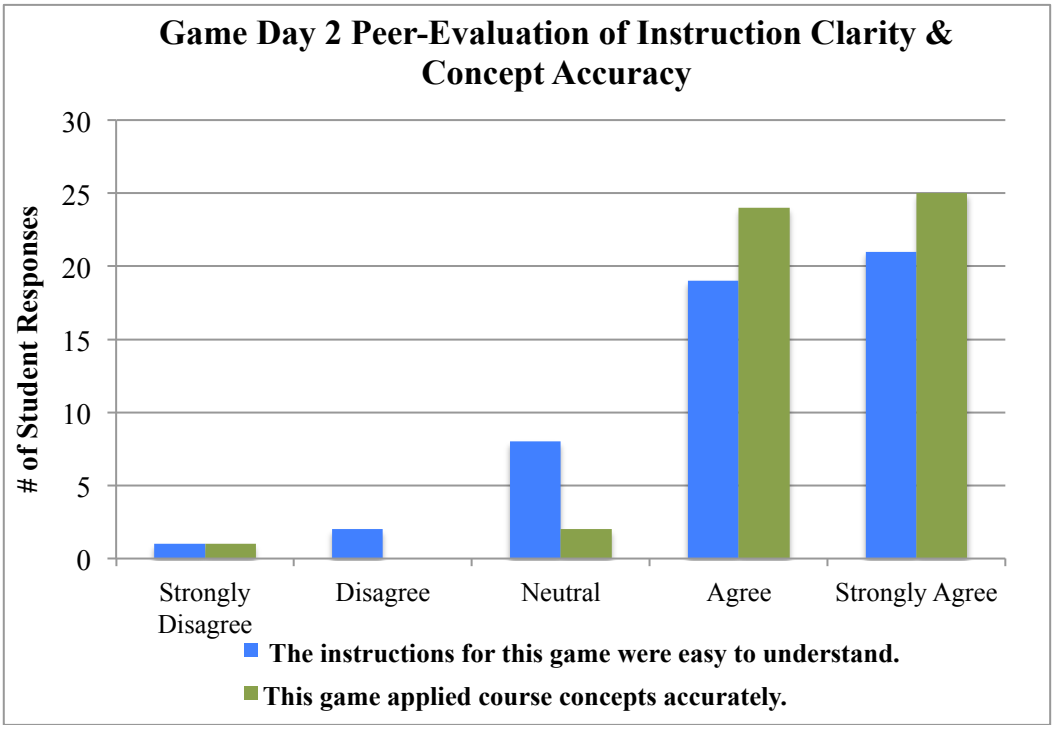

Figure 1: Peer-Evaluation of Instruction Clarity and Concept Accuracy Post-Game Day 2.

After participating in Game Day 1, game-design day, and Game Day 2, game-analysis day, students claimed that their peers' game design contained clear instructions and applied course concepts; greater than 50% of students agreed or strongly agreed that game designs included instructions that were easy to understand and applied course concepts with accuracy (Figure 1). The results show that less than 10 student's responses were neutral for instruction clarity and less than 5 were neutral for concept accuracy. Less than 2 students disagreed or strongly disagreed that their peers' instructions were easy to understand and their peers applied course concepts with accuracy in their game design (Figure 1). In evaluating the weaknesses of the game design, student responses showed that there were multiple areas for improvement; students cited 'other (fill in blank)' as leading weakness of the game design (Figure 2). Students provided in their fill-in-the-blank answer three common trends in game weaknesses, including game timing, number of game pieces and the difficulty of game questions for an audience (the students) that came from a wide range of experience and education levels. Instructions and board/game piece design was revealed to be two lesser weaknesses of their peers' games. The student responses, however, also showed that the leading strength of the game design was their peers' application of course concepts for game-play (Figure 2). Instructions, scoring of game and board/game piece design was revealed to be three lesser strengths of their peers' games.

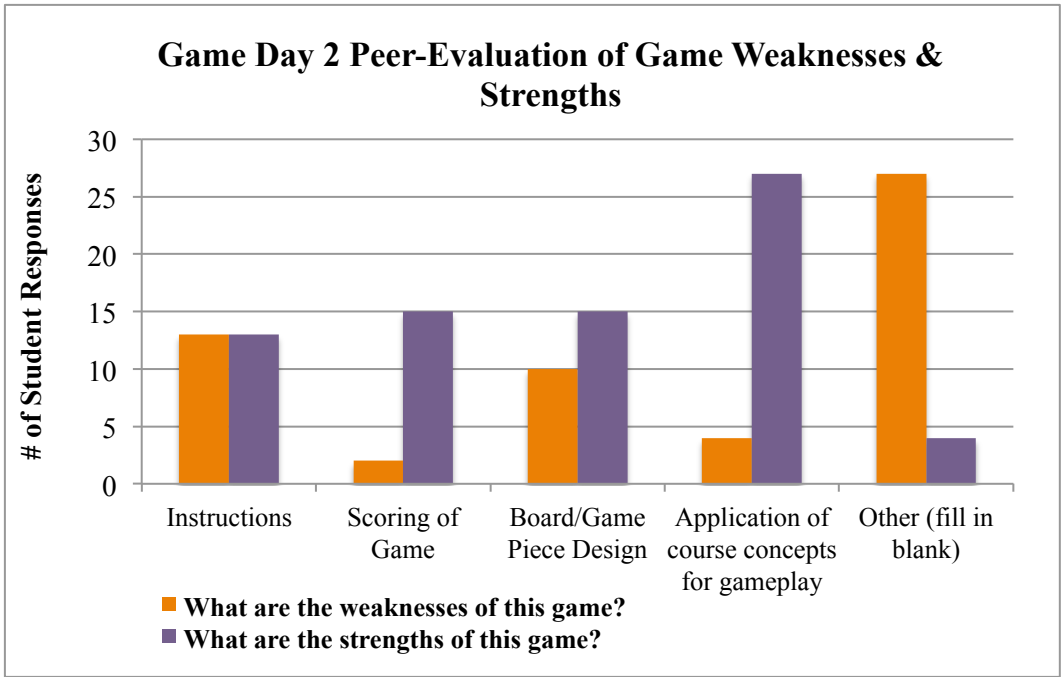

Figure 2: Peer-Evaluation of Game Weaknesses and Strengths Post-Game Day 2.

After participating in the final game day, Game Day 3, students took a similar questionnaire to that of the post-Game Day 2 questionnaire. Students claimed that their peers' game design contained clear instructions and applied course concepts; greater than 50% of students rated their agreed or strongly agreed that their game designs included instructions that were easy to understand and applied course concepts with accuracy (Figure 3). No students disagreed or strongly disagreed that their peers' instructions were easy to understand and their peers applied course concepts with accuracy in their game design (Figure 3), an improvement from Game Day 2.

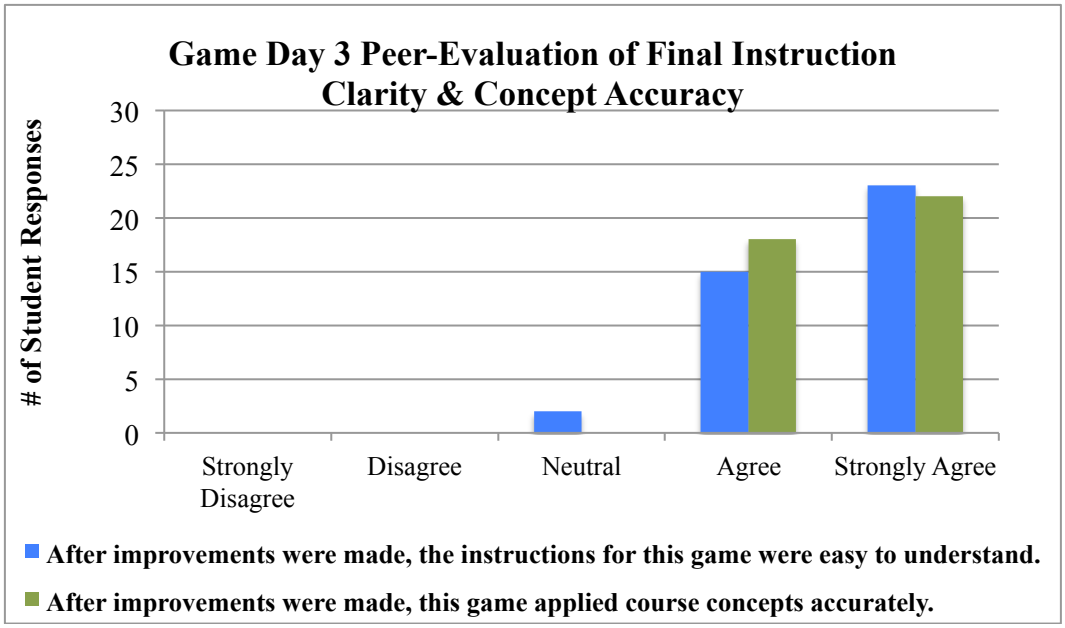

Figure 3: Peer-Evaluation of Final Instructions and Concepts Post-Game Day 3.

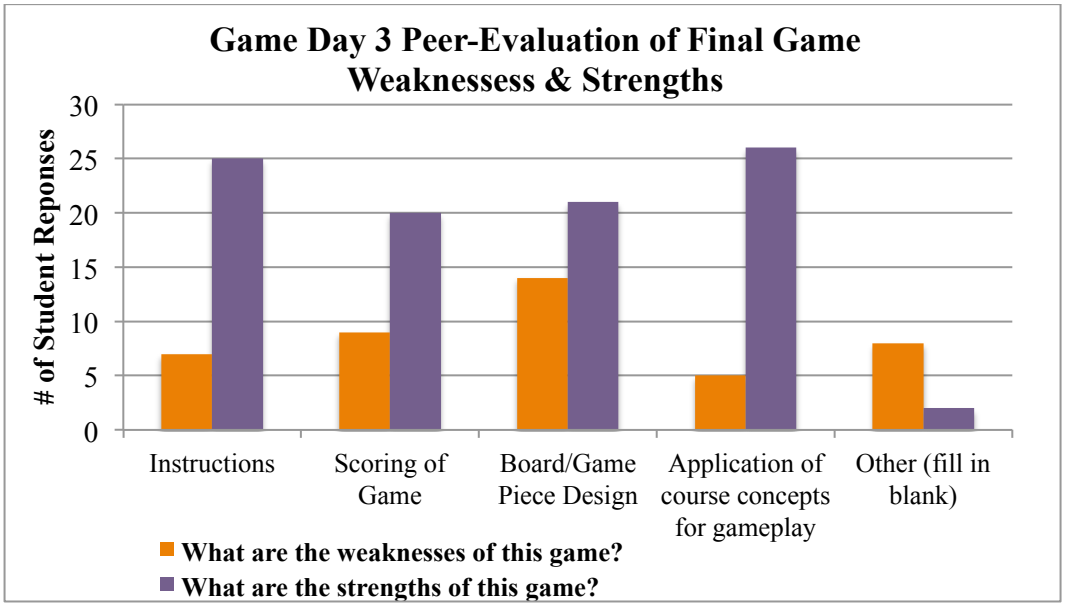

Figure 4: Peer-Evaluation of Final Weaknesses and Strengths Post-Game Day 3.

In evaluating the weaknesses of the game design, student responses showed that there were still multiple areas for improvement; students cited 'board/game piece design' as leading weakness of the game design (Figure 4). Between Game Day 2 and Game Day 3, students were able to correct the three common trends in game weaknesses, including game timing, number of game pieces and the difficulty of game questions, improving the games overall. All other categories revealed that the games still have weaknesses; however, when compared to Game Day 2 the weaknesses are less, with the exception of the game scoring, which students reported as an increased weakness compared to Game Day 2. There are two main explanations for this result; students changed their instructions after Game Day 2 peer evaluations, which could have

impacted/changed the scoring and students also spent less time on Game Day 2 scoring games due to instruction clarity, meaning that reports of scoring weaknesses were not evident until students actually played an entire game out on Game Day 3 once games were completed (Figure 4).

The student responses showed that the leading strength of the game design was their peers' application of course concepts for game-play followed by instructions, board/game piece design and scoring of the game (Figure 4). Students made significant updates post Game Day 2 after receiving their peers' evaluations on instructions, board/game piece design and scoring of game.

The results when students were asked to evaluate the use of these games both as a way to increase/practice applying their knowledge of course concepts revealed that greater than 50% of the students agree or strongly agree that these game design days and games allowed them to practice applying their knowledge of course concepts. Greater than 50% of the students agree or strongly agree that they would recommend the games created in this course to be used by future students taking this course (Figure 5). These results showed promise for the use of games as a way to engage students in the course concepts and allow them to practice applying course concepts in a hands-on, active, experiential manor.

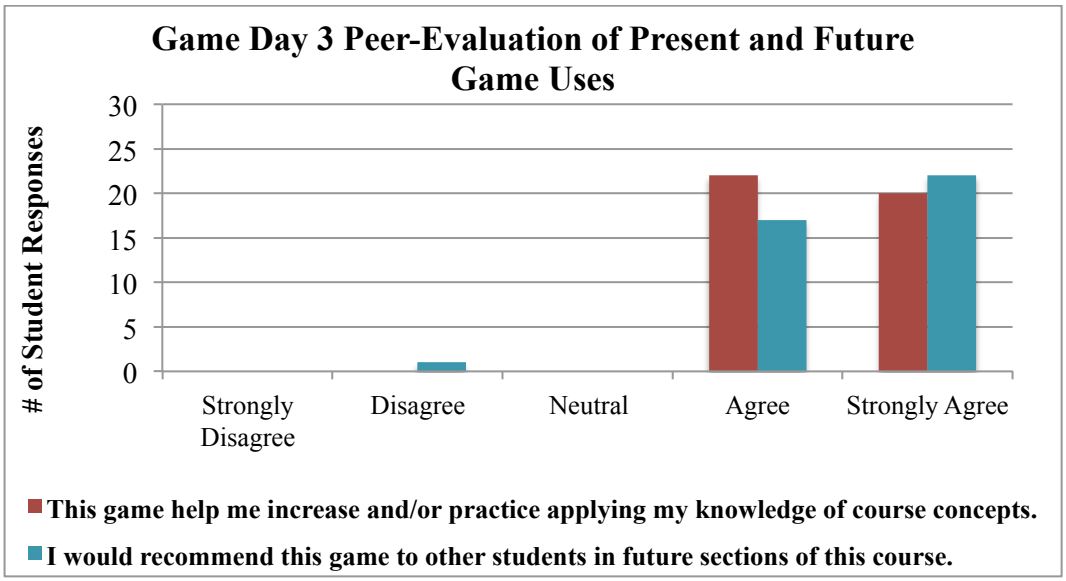

Figure 5: Peer-Evaluation of Usefulness of Games Post-Game Day 3.

The accuracy of game learning objectives accuracy is shown in Figure 6, Bloom's level of intellectual behavior evident in the game in Figure 7, and overall professionalism and effectiveness of the game in Figure 8 [1]. According to the instructor, 80% of the student games achieved accuracy or high accuracy of learning objective incorporation into the games (Figure 6). This result shows promise for the use of games as a learning technique post-learned material in a course. However, because 20% of the student games fell behind accuracy in receiving neutral or inaccurate scoring from the instructor, it is clear that not all students grasp the concept of meeting learning objectives.

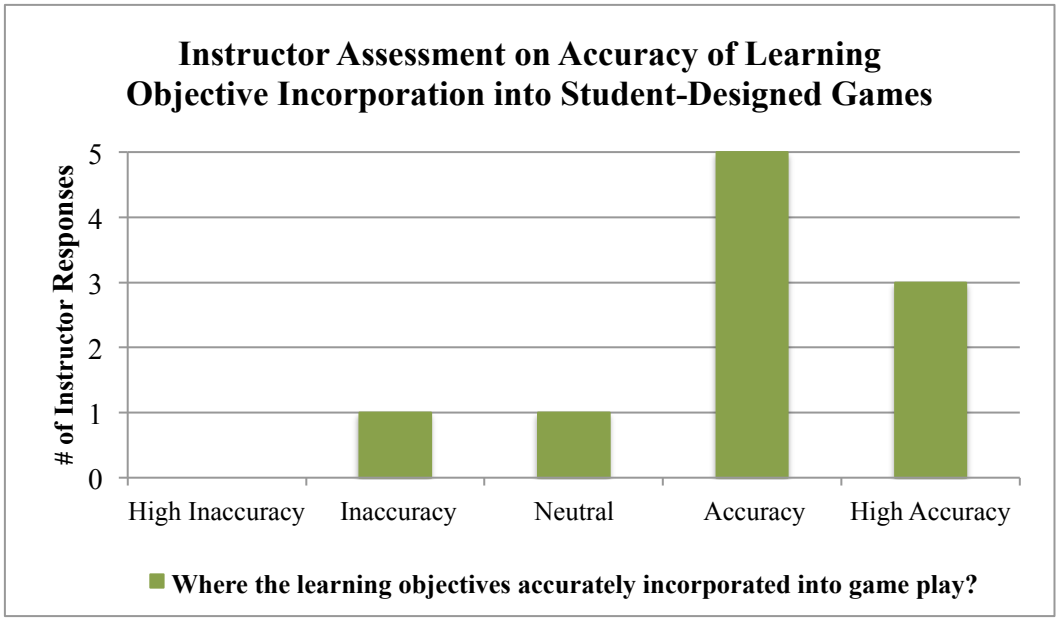

Figure 6: Instructor Assessment of Learning Objectives Incorporated into Student-Developed Games.

Figure 7 depicts the instructor's assessment of the Bloom's level of intellectual behavior evident within the student-designed games. The results show that 80% of the student games focused on understanding course content, 1 game focused on remembering and 1 game achieved applying. The course, CON 252, operates at the remembering-understanding level. The student group that achieved applications of course concepts was able to utilize scenarios in the case studies and field trips throughout the semester and apply course concepts within these scenarios. This was an unexpected but promising result.

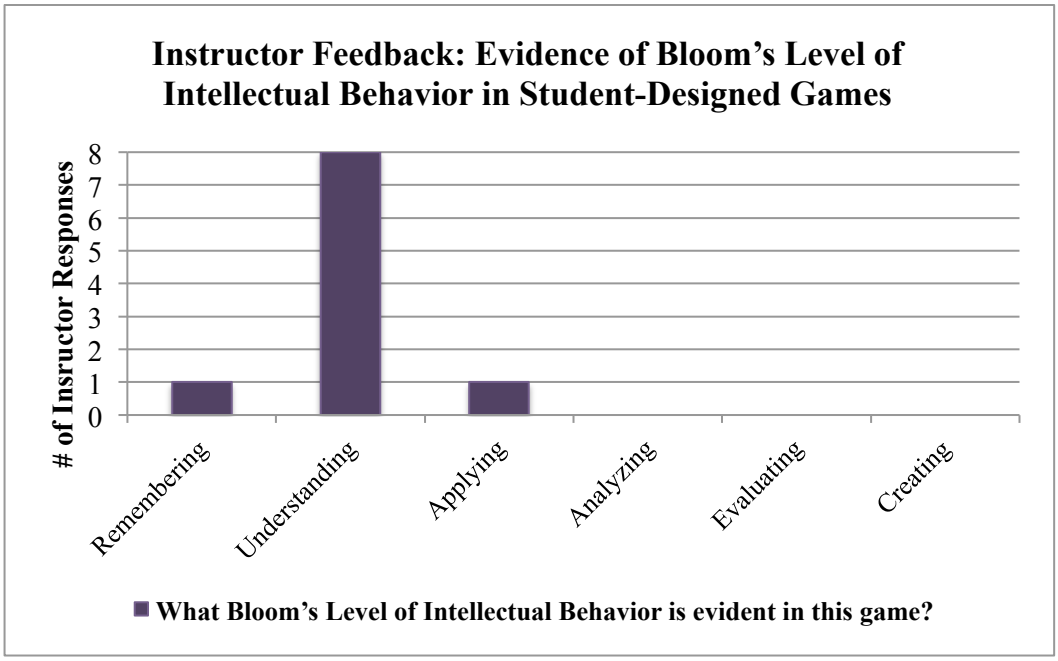

Figure 7: Instructor Assessment of Bloom's Level Achieved in Student-Developed Games.

Figure 8 depicts the instructor's assessment of the student-developed games based on professionalism and effectiveness. The results show that 50% of the games were rated as agree or strongly agree, where as the remaining 50% of the games were rated as neutral or disagree; overall the instructor did not find the game design professional or effective. These results highlight areas where instructions may have been lacking for the students constructing games and show improvements can be made to improve the game outcomes.

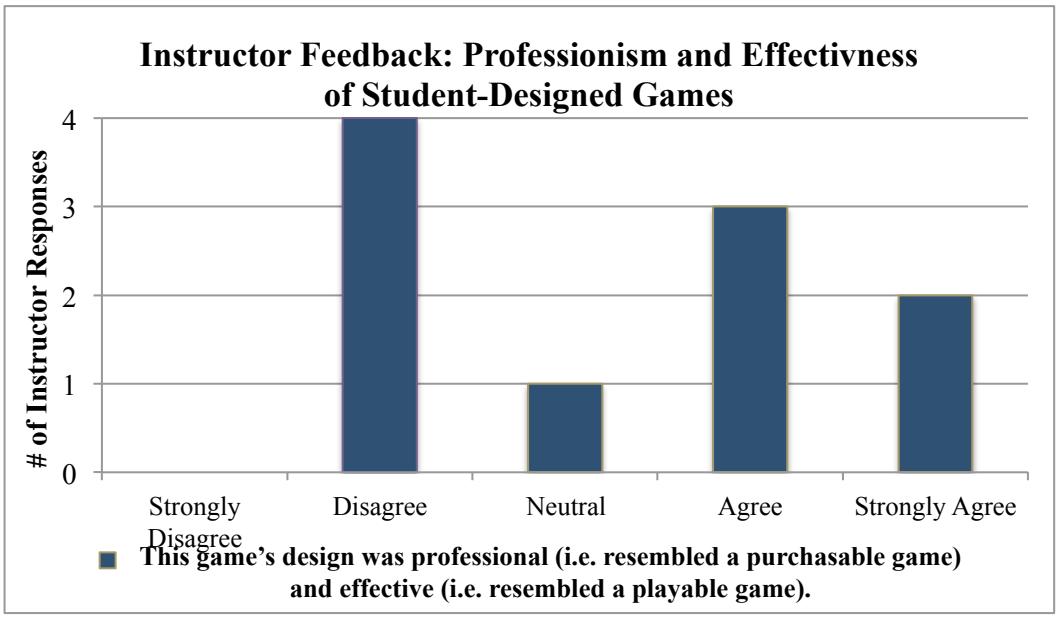

Figure 8: Instructor Assessment of Professionalism and Effectiveness of Student-Developed Games.

The results from the instructor's analysis of the self-reflection journal entries submitted by the students post-Game Day 3 revealed that the students were generally pleased with the game design days. The majority of the students reported that they felt the games helped them practice using concepts that they learned in class in a fun and exciting context. Students liked that they were afforded the opportunity to be creative in class, a component they see as a critical part of success in their future careers. Students were only negative about the fact that the game design days coincided with another class project; students would prefer to do one assignment or the other. The instructor received this feedback and found it useful to use in altering the syllabus for future semesters.

Conclusion

In this pilot study, 56 freshman through senior level introductory construction students in a class entitled Building Construction Materials, Methods, and Equipment developed 10 construction-themed games. Students modified existing games as well as created their own game pieces to meet student-defined learning objectives that covered concepts learned in the course. Greater than 50% of students agreed or strongly agreed that the game-design process helped them increase and/or practice applying their knowledge of course concepts. The instructor of the course rated the learning objectives achieved within the games as accurate of highly accurate for 80% of the games and 80% of the students' games achieved the level of Bloom's associated with

the course, understanding. Improvements can be made to the instructions for constructing the game; only 50% of the game designs were professionalism and effective. Overall, students reported that they recommend the games design days in their section to future sections of the course. These results showed promise for the use of student-designed games as a way to engage students with course concepts and allow them to practice applying them in a hands-on, active, experiential manor. The instructor incorporated feedback from this pilot study into the CON 252 syllabus and assignments for the Spring 2014 semester and will test the hypothesis that the student-developed games will be more professional after the assignment was refined based on student feedback.

Acknowledgements

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