2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC

Host Sponsor UNC Charlotte

Paper ID #53369

Sandbox to Guardrails: Comparing Learning Outcomes in Different Approaches of Project Based Learning

Dr. Jessie E Cossitt Ph.D., Mississippi State University

Jessie Cossitt is an Assistant Teaching Professor in the Department of Computer Science and Engineering at Mississippi State University. She teaches classes in Introduction to Algorithms, Theory and Implementation of Programming Languages, Human-Computer Interaction, and Discrete Structures. She partners with industry and academia clients to giver her Human-Computer Interaction students hands-on, real-world experience interface design and development. Her primary focus in educational research is studying learning outcomes in project-based learning environments.

Christopher Hudson, Mississippi State University
Daniel Wade Carruth, Mississippi State University

Sandbox to Guardrails: Comparing Learning Outcomes in Different Approaches of Project Based Learning

Abstract

Project-based learning provides students with valuable opportunities to explore unknowns and learn through experience and discovery, but providing these experiences presents a variety of challenges on the part of the course designer. This study highlights the lessons learned over the course of two iterations of a project-based learning class. In both iterations of the project, graduate and undergraduate students in Mississippi State University's split-level course, CSE 4663/6663 Human-Computer Interaction were tasked with working in five-person teams to design and develop multi-view graphical user interfaces (GUIs) for use in the supervision of off-road autonomous vehicles in a partnership with the Center for Advanced Vehicular Systems (CAVS) at Mississippi State University. In the first iteration of the project which took place in the fall semester of 2024, students were given an open-ended project and provided with a simulation built inside the Mississippi State University Autonomous Vehicle Simulator (MAVS). In addition to this simulation environment, students were provided with a ROS bridge package that exposed the autonomous vehicle data inside the Robot Operating System (ROS). Students then implemented backend interfaces using Robot Web Tools libraries to provide data to their designed interfaces. Observation of students during this project suggested that the scope was potentially too broad for optimal learning. With the hypothesis that student learning outcomes would improve with a more structured project environment, the second iteration of the project, which took place in the fall semester of 2025, put more guardrails into place for students who were provided with a controlled set of implementation constraints including standardized hardware and software as well as specific data for testing. This included providing each student team with a Raspberry Pi 5 equipped with Ubuntu and ROS 2, a 12inch screen, access to Robot Web Tools libraries, and a ROS 2 bag with approximately 30 seconds of simulation data for testing. The learning outcomes of the two iterations of the course were compared by having students from both classes fill out an instrument for evaluating self-reported learning outcomes adapted to suit a project-based course on interface design and development. The comparison of these approaches allows for discussion on best practices in problem-based learning, specifically how the balance among student freedom, instructor guidance, and project structure can impact learning outcomes and student experiences in project-based learning classrooms.

Introduction

One of the main goals of project-based learning is to allow students to develop a deeper understanding of materials and more advanced critical thinking skills than more traditional pedagogical approaches [1]. In this approach, students take part in hands-on projects with the instructor of the course acting as a guide while projects are usually, to some degree, open-ended, giving students the opportunity to investigate the problem-space and make decisions about their approach [2]. When implementing a project-based learning course, instructors must decide what ratio of structure to freedom students will be provided with when working their way through the project. Studies show that while self-direction is an important component in project-based learning [3], some amount of scaffolding is also needed to maximize the depth of knowledge students retain [4][2].

Project-based learning approaches are often evaluated by measuring learning outcomes at the end of the project or relevant course. This can be done using the results of students' assessments in the course [1][5] as well as via student self-assessment [6][7][8]. While, there is a breadth of research supporting project based learning as a whole [9][10][11], research comparing different implementations of project-based learning is more limited.

The Human-Computer Interaction course at Mississippi State University has been partnering with the Center for Advanced Vehicular Systems (CAVS) at Mississippi State University for the past two years to provide students the opportunity to gain experience doing interface development for a client over the course of a semester long project-based learning assignment. In this project students were tasked with developing an interface to supervise the activity of an autonomous off-road vehicle (see Figure 1) [12]. This work compares two iterations of this project between which significant changes were made to the presentation of the project based on feedback and observations of student performance.

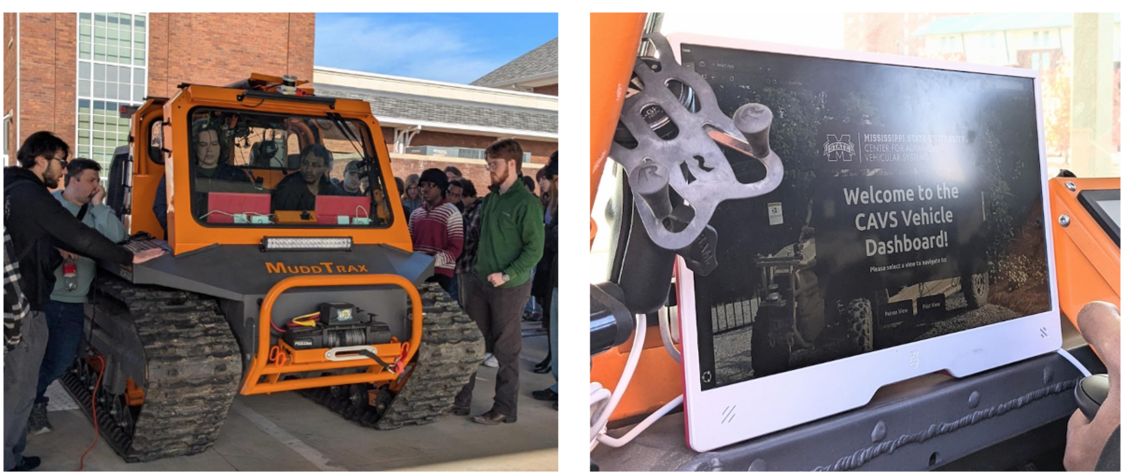

Figure 1: Students Demonstrating Their Design in the Vehicle

Methods

In both iterations of the off-road autonomy project, students were grouped into teams of five and told that they were to create a GUI to display multiple views of information based on live data being received from the vehicle. In both years students were also given the opportunity to distribute tasks among their team based on their own judgment of members' strengths, were given formal feedback at two mid-semester checkpoint presentations, and were able to contact members of the CAVS team via in-person meetings, group chats, email, and classroom visits.

In year one of the project, in addition to the project description, students were provided with access to a vehicle simulation built inside the Mississippi State University Autonomous Vehicle Simulator (MAVS) as a source of data for testing their designs as well as a ROS bridge package that exposed the autonomous vehicle data inside ROS. The students were free to make any other choices they wanted with the instructor and CAVS team available to them for guidance

In year two of the project, in addition to the project description, students were provided with a controlled set of implementation constraints including standardized hardware and software as well as specific data for testing. This included providing each student team with a Raspberry Pi 5 equipped with Ubuntu and ROS 2, a 12 inch screen, access to Robot Web Tools libraries, and a ROS 2 bag with approximately 30 seconds of simulation data for testing.

The changes to make the year two iteration of the project more constrained were made to directly address multiple observations made in year one. The first was that students seemed to be overwhelmed by the project, struggling to find a starting point even with guidance. The second was that students had difficulty optimizing the simulation in MAVS to run on the equipment they had access to. The third was that the scope of the project was too big when including the time it took for students to research and decide on software options. The goal of constraining the project was to allow students to have more time to focus their efforts and apply independent decision making abilities on the central focus of the course which was interface design.

Data collected for this study included self-reported data from students and scoring of the students' final interfaces by the instructor and CAVS team. The goal of these two metrics was to analyze both the students' perceptions of their learning and the quality of the work they produced.

Students in both iterations of the course took part in a self-evaluation survey to rate their learning objectives for the course (see Figure 2). This survey was made based on the self reported instrument for measuring student learning outcomes created by Jones and modified to suit the course's learning outcomes [6]. Consistent with the original survey, this survey investigates each of the course's learning outcomes in three different ways by having students rate the amount of time spent on the learning outcome, the quality of activities in the course related to the learning outcome, and how much they agree that the course improved their abilities related to the learning outcome. The learning outcomes included applying theories of interaction design to real-world problems, analyzing open-ended problems, effectively working in a team, delivering professional demonstrations to clients, and determining the steps necessary for completing a project. The surveys were analyzed numerically by assigning a point value to each response option on a scale of 1 to 5 with 1 being the first listed option (way too little, very poor, or strongly disagree) and 5 being the last listed option (way too much, exceptional, or strongly agree).

Self-Reported Learning Outcomes for Human-Computer Interaction

1. How much time did this course spend on applying theories of interaction design to real-world problems

   ○ Way too little ○ Too little ○ Just right ○ Too much ○ Way too much

2. How would you rate the quality of activities in this course to support learning how to apply theories of interaction design to real-world problems

   ○ Very poor ○ Poor ○ Satisfactory ○ Very Satisfactory ○ Exceptional

3. Rate how you agree with the following statement: This course has improved my ability to apply theories of interaction design to real-world problems

   ○ Strongly disagree ○ Disagree ○ Neither agree nor disagree ○ Agree ○ Strongly agree

4. How much time did this course spend on analyzing open-ended problems

   ○ Way too little ○ Too little ○ Just right ○ Too much ○ Way too much

5. How would you rate the quality of activities in this course to support learning how to analyze open-ended problems

   ○ Very poor ○ Poor ○ Satisfactory ○ Very Satisfactory ○ Exceptional

6. Rate how you agree with the following statement: This course has improved my ability to analyze open-ended problems

   ○ Strongly disagree ○ Disagree ○ Neither agree nor disagree ○ Agree ○ Strongly agree

7. How much time did this course spend on effectively working in a team

   ○ Way too little ○ Too little ○ Just right ○ Too much ○ Way too much

8. How would you rate the quality of activities in this course to support learning how to effectively work in a team

   ○ Very poor ○ Poor ○ Satisfactory ○ Very Satisfactory ○ Exceptional

9. Rate how you agree with the following statement: This course has improved my ability to effectively work in a team

   ○ Strongly disagree ○ Disagree ○ Neither agree ○ Agree ○ Strongly agree

10. How much time did this course spend on delivering professional demonstrations to clients

    ○ Way too little ○ Too little ○ Just right ○ Too much ○ Way too much

11. How would you rate the quality of activities in this course to support learning how to deliver professional demonstrations to clients

    ○ Very poor ○ Poor ○ Satisfactory ○ Very Satisfactory ○ Exceptional

12. Rate how you agree with the following statement: This course has improved my ability to deliver professional demonstrations to clients

    ○ Strongly disagree ○ Disagree ○ Neither agree ○ Agree ○ Strongly agree

13. How much time did this course spend on determining the steps necessary for completing a project

    ○ Way too little ○ Too little ○ Just right ○ Too much ○ Way too much

14. How would you rate the quality of activities in this course to support learning how to determine the steps necessary for completing a project

    ○ Very poor ○ Poor ○ Satisfactory ○ Very Satisfactory ○ Exceptional

15. Rate how you agree with the following statement: This course has improved my ability to determine the steps necessary for completing a project

    ○ Strongly disagree ○ Disagree ○ Neither agree ○ Agree ○ Strongly agree

Figure 2: Self Reported Learning Outcomes Survey

Groups in both years were also rated by the instructor and the CAVS team using the System Usability Scale (SUS), a common usability scale that has a user rate a system by answering ten questions on a scale of 1 to 5 [13]. The scale combines factors of systems effectiveness, efficiency, and satisfaction and produces a final score between 0 and 100 with the mean being a score of 68 [14].

Results

Results showed that students in year one rated their learning higher while the quality of student work was rated higher in year two

Analysis of the students' self reported learning outcomes using the Wilcoxon rank-sum test to compare responses between years showed a statistical difference in responses for only one question. Question 3 in the survey, "rate how you agree with the following statement: This course has improved my ability to apply theories of interaction design to real-world problems," had a significantly higher rating from students in year 1 than in year 2 ($p=0.023$) (see Figure 3).

Results of the system usability scale as rated by the instructor and CAVS members were analyzed using a two-tailed T-test to compare scores between year 1 and year 2. The results of this test showed statistically higher ratings for projects in year 2 than in year 1 ($p = 0.024$). The mean score for the year 1 projects was 55.28, and the mean score for the year 2 projects was 79.38.

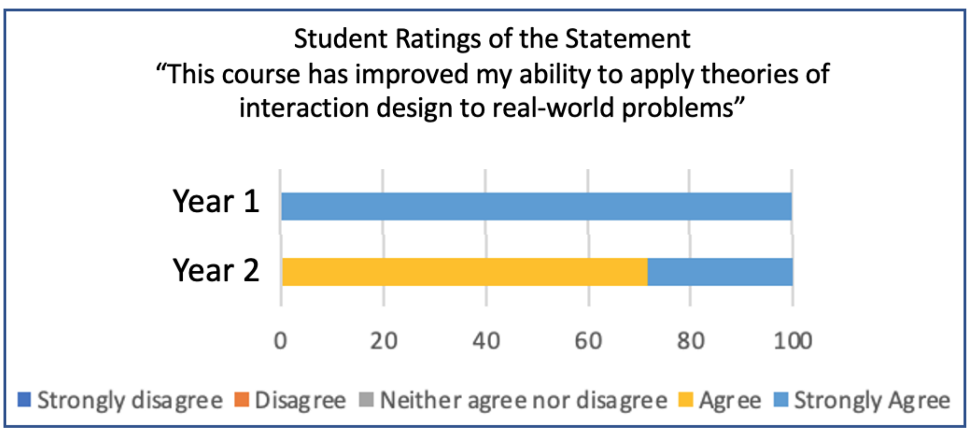

Figure 3: Results of Survey Question 3

Discussion

The results of this study suggest a disconnect between the quality of students' work and their own ratings of their learning. While the changes to the project from year one to year two accomplished the goal of improving quality by adding constraints, students' self-rated learning outcomes did not improve in any category and significantly dropped in one. Students perceived how well the course taught them to apply theories of interaction design to real-world problems to be to be greater in year 1 with a much more open ended project than in year 2 with more constraints.

This study demonstrates the value of student independence in decision making when it comes to how they perceive their learning outcomes. It continues to be the case that the balance between this independence and instructor guidance is important to help students produce quality work and progress at an acceptable rate while retaining the value of independent learning and discovery.

References

[1] B. Prince, “Project-based learning (pbl) for developing critical thinking skills in engineering students,” in *In Proceedings of the 2025 ASEE Anual Conference and Exposition*, 2025.

[2] A. Shekar, “Project based learning in engineering design education: Sharing best practices,” in *In Proceedings of the 121st ASEE Annual Conference and Exposition*, 2014.

[3] E. H. J. Yew and K. Goh, “Problem-based learning: An overview of its process and impact on learning,” *Health Professionals Education*, vol. 2, pp. 75–79, 2016.

[4] M. H. Rahman, “Analysis of the teacher’s role as a facilitator in project-based learning to enhance student creativity,” *The Journal of Academic Science*, vol. 2, 2025.

[5] D. C. Davis, K. L. Gentili, M. S. Trivisan, R. K. Christianson, and J. F. McCauley, “Measuring learning outcomes for engineering design education,” in *In Proceedings of the 2000 ASEE Annual Conference and Exposition*, 2000.

[6] T. L. Jones, “Self reported instrument for measuring student learning outcomes,” in *In Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition*, 2003.

[7] Z. Rahman, S. K. Madanu, S. P. Mattingly, and C. Casey, “Project-based learning for enhancing students’ knowledge on active commutin: A review from student self asessment,” in *In Proceedings of the 2006 American Society for Engineering Education Gulf-Southwest Section Conference*, 2006.

[8] C. Aranzazu-Suescun and L. F. Zapata-Rivera, “Learning outcomes as a self-evaluation process,” in *In Proceedings of the 2023 ASEE Annual Conference and Exposition*, 2023.

[9] B. Galand, M. Frenay, and B. Raucent, “Effectiveness of problem-based learning in engineering education: A comparative study on three levels of knowledge structure,” *International Journal of Engineering Education*, vol. 28, no. 4, pp. 939–947, 2012.

[10] R. Simbolon and H. D. Koeswanti, “Comparison of pbl (project based learning) models with pbl (problem based learning) models to determine student learning outcomes and motivation,” *International Journal of Elementary Education*, vol. 4, pp. 519–529, 2020.

[11] L. H. Distlehorst and R. S. Robbs, “A comparison of problem-based learning and standard curriculum students: Three years of retrospective data,” *Teaching and Learning in Medicine*, pp. 131–137, 2009.

[12] C. R. Hudson, J. E. Cossitt, and D. W. Carruth, “Empowering student skill development in robotics through autonomous research engagement,” in *In Proceedings of 23rd International Conference on Emerging eLearning Technologies and Applications (ICETA)*, 2025.

[13] J. Brooke, “Sus – a quick and dirty usability scale,” *In book: Usability Evaluation in Industry*, pp. 189–194, 1996.

[14] M. Hyzy, R. Bond, M. Mulvenna, L. Bai, A. Dix, S. Leigh, and S. Hunt, “System usability

scale benchmarking for digital health apps: Meta-analysis," *JMIR Mhealth Uhealth*, pp. 189–194, 2022.