Comparison of the Effectiveness of Company-sponsored versus Student-selected Project-based Learning in Online Database Classes

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ABSTRACT

This research-to-practice full paper describes our comparative analysis of two different project-based learning (PBL) practices to identify determinant factors in PBL that can motivate and enhance student learning. Project-based learning, a widely recognized form of experiential learning, employs the "learning by doing" approach to help students build concrete knowledge through hands-on experience. Numerous studies have demonstrated that this knowledge transformation process can significantly enhance students' critical thinking and problem-solving skills, while also boosting their motivation and engagement. However, there is a lack of research comparing different PBL practices to pinpoint the essential design elements that maximize student learning.

Our study focuses on half-term long PBL practices in online undergraduate database classes with similar demographics, where except for the differences in project-based learning practices, all others in two sections were the same. We compare company-sponsored projects with student-selected projects to analyze how these different approaches impact student learning outcomes and what could be determinant factors influence student project-based learning.

Student-selected project-based learning allows students to choose their own data domain of interest. Company-sponsored project-based learning grants students less freedom in topic selection but could provide students with opportunities to collaborate with company professionists and learn the real needs from industry and have a potential to secure an intern job, though there exists uncertainty and unpredictability in the collaboration. Both project-based learning practices vary in the following five characteristics that influence projects: (1) Centrality, (2) Driving question, (3) Constructive investigations, (4) Autonomy and (5) Realism.

Our comparative analysis reflects the inherent variations in complexity and difficulty between the two types of PBL practices. We conducted two surveys to investigate student perceptions of their project experiences. We developed a web dashboard to conduct comparative analysis for a more general purpose. Through quantitative analysis of student performance and engagement time, as well as qualitative analysis of survey responses, we identify statistically significant determinants that influence the effectiveness of PBL. This study lays the groundwork for designing guidelines to facilitate effective project-based learning.

CCS CONCEPTS

Information Systems -> Data Management Systems -> Database Design and Models -> Relational Database Model;
Information Systems -> Data Management Systems -> Database Design and Models -> Entity Relationship Models;
Information Systems -> Data Management Systems -> Database Administration -> Database Utilities and Tools;
Applied Computing -> Education -> Collaborative Learning;Applied Computing -> Education ->E-learning

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KEYWORDS

Project-based learning, experiential learning, database management system (DBMS), database design and implementation, database development lifecycle, agile process model

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1. INTRODUCTION

Computer Science Curriculum (2023) [1, 2] has stated that today's graduates are expected to possess practical database management system (DBMS) user skills, primarily including the abilities to data modeling and query construction. This is a high-order synergic ability, applying software engineer best practices in database design and implementation to ensure quality attributes such as maintainability and tractability. Many fundamental topics in

software engineering and database management benefit best in a hands-on fashion. Project-based learning pedagogy could be a common vehicle for such learning, where students learn by actively engaging in real-world and personally meaningful projects.

Project-Based Learning comes in many forms and sizes, although all of them often require students to actively participate in the learning process by accessing content, managing work, collaborating, designing, revising, sharing ideas, and reflecting on their own thinking resources. There are many research works exploring project-based learning in different domain contexts [3-8]. Student-selected projects and company-sponsored projects emphasize student control on projects at different levels, possibly causing different effects on student learning, which has been rarely studied in literature.

In Spring 2023, authors had an opportunity to offer two online asynchronous sessions respective of 89 students. The mean GPA of entering students in one section has no statistically significant difference in the other section (3.336 and 3.334). Authors conducted project-based learning respectively in both sections, one section with student-selected project (also called student-centered project), where students choose a database-oriented topic of their interest and develop a relational database, and the other section with company-sponsored project (also called company-guided project), where company specified requirements and input data. Both projects were team-based eight weeklong. Except for the differences in project-based learning practices, all others in two sections were the same, for example, learning content, course/module/project outcomes, activities, assessments, and even the deadlines. Instructors gave students the same level of details in project instructions and project grading criteria, and teaching assistants (TAs) used the same rubrics for all grading items.

Based on course curriculum, the project-based learning outcome is to enable students to employ agile process model in database development lifecycle, collect and analyze user requirements, take an unorganized collection of data, conduct conceptual database design, create an Entity-Relationship Diagram (ERD) to accurately represents the business logic, convert the conceptual design to a logical data model, address potential data integrity issues and redundancy, normalize it, translate the logical model into a physical database schema, access/update the collection via queries, and organize it using a DBMS.

However, the quality of project performance may vary between these two practices, since there are many factors influencing student motivations, for example, company-involving format, the input data scale, domain problem itself, project settings, and student collaborations or interactions with company “sponsors”, all of which may cause different effects on project-based learning.

In this paper, we investigated the efficacy of student-selected project learning against company-sponsored project learning. We conducted a series of comparative analysis on the overall performance, engagement, and reflections of these two sections in our dashboard website (under the review). Our research question is whether company-sponsored project-based learning motivated student learning better and promoted student learning.

In the following sections, we are going to give a literature review on project-based learning. Then, we present the institutional context of this database course and present more details about our practices on student-selected project learning and company-sponsored project-based learning, followed by a section of comparative analysis. In the end, we are going to discuss the limitations and possible future work.

2. PROJECT-BASED LEARNING

The project-based learning methodology (or PBL method of teaching) is a way to structure curriculum around projects that promote inquiry-based activities [4]. It is one popular type of active learning, through which students collaborate in groups, work on projects to solve real-life problems, deeply engage and actively participate in their own learning process [4]. The “learning by doing” approach combines theory and practice, providing students opportunities to construct concrete knowledge by experience and improve students’ self-efficacy [3,11].

There are different forms of project-based learning, and many factors influence the effects of this pedagogy. Thomas [6] identified five characteristics that influence projects: (1) Centrality, (2) Driving question, (3) Constructive investigations, (4) Autonomy and (5) Realism. Authors in [7, 8] emphasized the importance of student collaboration, reflection, redrafting, and presentations. Authors in [9] highlighted effective scaffolded instruction within high-quality experiences.

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Student-selected project-based learning allows students to choose their own data domain of interest. The freedom and challenge that students experience in designing and building their projects facilitated engaging students and stimulating student interest in learning [5]. The drawback is that students might feel difficult in resolving conflict caused by team member’s different interest or needs.

Company-sponsored project-based learning attracted students due to the great opportunities to collaborate with company professionists to learn the real needs from industry and have a potential to secure an intern job. The drawback is that there exists uncertainty and unpredictability in the collaboration.

There are many research works exploring project-based learning in different domain contexts [3-8]. There are rarely studies in comparing student-selected projects and company-sponsored projects to provide guidelines for better project-based learning.

Timelines	Section 052	Section 053
Timeline 1	High-level requirements gathering and analysis, and high-level conceptual design.	Analyze the client spreadsheet table, identify functional dependencies, transform it to Boyce–Codd normal form (BCNF), and create database logical design.
Timeline 2	Identify and concretize high priority requirements, perform conceptual, logical, and physical database design, finish ER model, map it to the relational schema, and create the physical schema.	Create tables and import data properly.
Timeline 3	Refine the requirements they have been working on, finish ER model, map it to the relational model, verify the database normal forms, and create tables and three key SQL queries.	Data integrity, backup and disaster recovery, and security implementations.
Timeline 4	Write necessary indexing, views, and stored programs.	Write necessary SQL queries, views, and stored programs, test their database design, and optimize database performance.

Table1. Timelines of course project in these two sections.

3. INSTITUTIONAL CONTEXT

This course is titled “Database Design and Implementation”, with a focus on the modeling, programming, and implementation of database systems. We emphasize teaching students how to create a well-structured, efficient, and effective database design that can meet the requirements of the application. One of the main goals of this course is to enable students to design a database from scratch and effectively implement it based on the design.

This course is a core technique course in the Data Science (DS) concentration, required for all DS undergraduate students. Data modeling skills that students learned from this course are essential for DS students. Thus, this course is critical to facilitate DS students to build up their skills and have a better understanding of data structure, relationships, integrity, quality, and scalability. It is also a prerequisite course for several senior elective technical courses.

The topics in the course include (1) modeling: conceptual data modeling, ER diagram, relational data model, schema design, normalization, and refinement; (2) programming: relational algebra and calculus, SQL, constraints, triggers, views; (3) implementation: data storage, indexing, query execution, query optimization, and transaction management.

There are two sections for the 3160 class with reference ID respectively of 052 and 053. Every section had 89 students. The students were graded based on textbook reading quizzes, labs, assignments, and two exams. The grading items and rubrics in both sections were also the same, and even the deadlines. Both had 12 textbook reading modules, seven labs, four assignments, one midterm, and a final exam. Textbook readings account for 36% of the grade, labs for 15%, assignments for 5%, project for 18% and exams for 20%. Additionally, 5% of the grade comes from miscellaneous surveys and reflections.

4. PROJECT-BASED PRACTICES IN DATABASE COURSES

4.1 Student-selected project-based learning

For section 052, students were required to form their own teams of 3-5 members at the end of the eighth week, and each group had the liberty to choose a database-oriented project topic of their choice and then develop a relational database-oriented system. Out of 89 students, three students worked individually under our permission and 86 students worked in groups. For their chosen topic, students worked on their project across four timelines and for each timeline (see Table 1), students were required to refine their design and implementation from previous timelines. After picking a topic, for timeline 1, they performed high-level requirements gathering and analysis as well as high-level conceptual design. For timeline 2 students identified and concretized high priority requirements, performed conceptual, logical, and physical database design, finished ER model, mapped it to the relational schema, and created

the physical schema. For timeline 3, students further refined the requirements they had been working on, finished ER model, converted it to the relational model, verified the database normal forms, and created tables and three key SQL queries. Finally for timeline 4, students wrote necessary indexing, views, stored programs, report, and slides for video presentation. On average, each group created about eight tables with relevant data in each table.

4.2 Company-sponsored project-based learning

For section 053, students worked on a company-sponsored project. The project requirements were provided by a company, named Wall Street Options branched with Wall Street Career and Wall Street Connect (short name as Wall Street Options/Career/Connect), working in conjunction with the class. The company is a recruiting agency, recruiting actual recruiters for other companies. The company needs were about converting their manually generated LinkedIn human resource spreadsheet data to a relational database. The students worked across 4 timelines. For timeline 1, students analyzed the client spreadsheet table, identified functional dependencies, transformed it to Boyce-Codd normal form (BCNF), and created database logical design. For timeline 2, they created tables and imported data properly. Timeline 3 delt with data integrity, backup and disaster recovery, and security implementations. For the final timeline 4, students wrote necessary SQL queries, views, and stored programs, tested their database design, backed up, discussed security and disaster recovery plan, and optimized database performance. Each group also wrote a report and gave an online presentation to the company director and the instructor.

The company provided data including a list of people and their contact information. The data is relatively straightforward and consists of 1333 rows and 9 columns (first name, last name, position, company, specialties, industry, city, state, and LinkedLn link). Each group of students get a subset of this data of 1000 randomly selected rows.

5. COMPARATIVE ANALYSIS

We conducted comparative analysis on the student-selected project section (052) as control group and the company-sponsored project section (053) as experiment group. At the beginning of the class, students in both sections filled out a survey indicating their confidence level in programming as well as in teamwork.

5.1 Student overall performance

We used the Mann-Whitney U Test to compare mean performance of students in the control (052) and experiment (053) sections. The Mann-Whitney U Test, also known as the Wilcoxon Rank Sum Test, is a non-parametric statistical test used to compare two samples or groups. Since all four assignments were released after the course project was released, we conducted the Mann-Whitney U test to examine whether the mean scores on these four assignments in control section was lesser than the mean scores in the experimental section. The results indicate a significant difference for all assignments (p-values= (0.04, 0.0004, 0.0001, 0.003)). It is observed that the students in section 053 performed better than students in section 052. We also observed better performance on the most of labs, the project (p-value=0.015), and the final exam (p-value=0.041) (see Figure 2).

We used Cohen's D [10] to calculate effect size, and namely, the difference in the means of a comparison condition between assessment scores in experimental section against the control section divided by the pooled standard deviation of these two sections. The highest effect sizes refer to assignments (effect size=0.424) and projects (effect size=0.315) (see Figure 2). We also examined student performance based on their programming confidence level or teamwork confidence level (see Figure 1 and 3). Figure 1 indicates that students who had higher programming confidence level performed better on average. Figure 3 shows that students who had somewhat confidence / somewhat unconfidence level performed better as well on average in company-sponsored section (053) than the student-selected section (052). These observations indicate that students were motivated and became more excited about their collaborative work in the company-sponsored section (053) than the student-selected section (052). Overall, students in the company-sponsored section (053) performed better than the student-selected section (052). Though this is not the case for all assessment items, for example, ZyBooks reading tasks. This is possibly because textbooks assignments have unlimited attempts and students can eventually get a high score after many attempts.

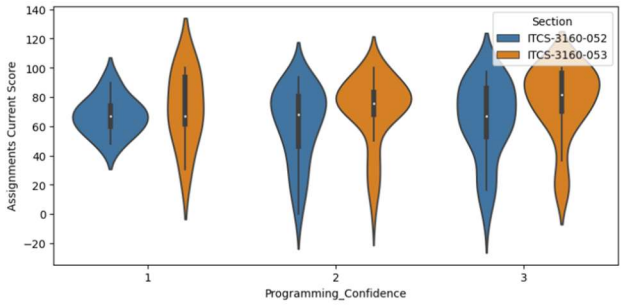

Figure 1. The violin plot of assignment score distribution of students in the student-selected section (052) against the company-sponsored section (053), grouped by student

programming confidence level. This plot indicates that students who had higher programming confidence level performed better on average and that students in company-sponsored section (053) performed better than the student-selected section (052).

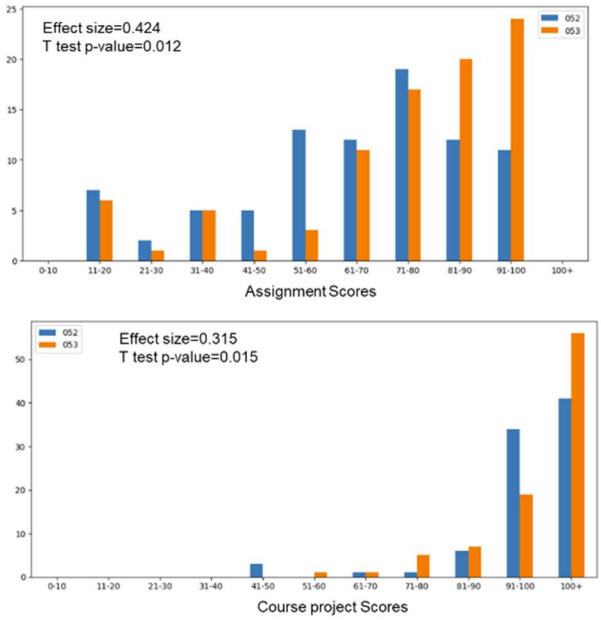

Figure 2. Histogram of student assignment scores and project scores in the student-selected section (052) against the company-sponsored section (053).

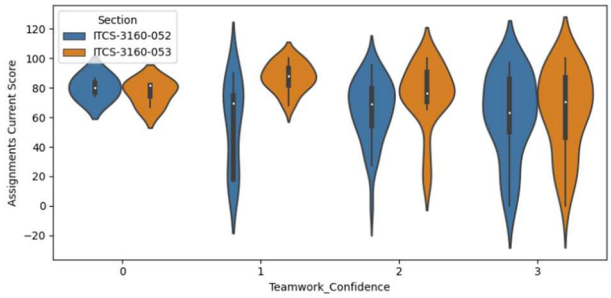

Figure 3. The violin plot of assignment score distribution of students in the student-selected section (052) against the company-sponsored section (053), grouped by student teamwork confidence level. This plot indicates that students who had somewhat confidence/ somewhat unconfidence level performed better on average in company-sponsored section (053) than student in the student-selected section (052).

Category	T test P-value	Effect size	Levene's test P-value	ANOVA P-value	KL Divergence
Total time (min)	0.005	0.399	0.446	0.011	0.264
Participation total time (min)	0.015	0.34	0.131	0.029	0.258
Challenge total time (min)	0.01	0.361	0.477	0.021	0.149
Lab total time (min)	0.084	0.215	0.685	0.167	0.238

Table 2. Statistical difference of engagement time distribution of students in the student-selected section (052) against the company-sponsored section (053), This experiment indicates that students in the student-selected section (052) spent less time in readings than students in the company-sponsored section (053)

5.2 Student engagement

We retrieved student engagement time on ZyBooks reading and activities for both sections and further we conduct comparative analysis on the engagement data.

We conducted the t test to examine whether the samples for the student-selected section (052) is less than that of section company-sponsored section (053) (see Table 2). Every test shows a significant result, indicating that the student-selected section spent much less time on Textbooks. We further checked the relative magnitude of the experimental treatment by Cohen's D effect sizes and the results fell in the range of 0.215 (ZyBooks lab activity engagement time) to 0.399 (ZyBooks total engagement time). Then we used the Levene's test to determine homogeneity of variance between these two sections. No significant p-values in column 4 of Table 2 was found, indicating that there was no significant difference in the F value, indicating that the null hypothesis of homogeneity of variance was tenable and the variance of samples for both sections is not homogenous. Furthermore, we conducted the one-way ANCOVA and KL Divergence to exclude the effects of prior knowledge on the research findings.

5.3 Project feedback analysis

We executed the same project feedback survey of 5-point likert scale at the end of the semester in both sections. Through the above-mentioned statistical methods on student responses from the control (052) and experimental (053) sections (see Table 3), we found that company-sponsored section (053) positively effects student learning more than student-selected section (052). Students believed that this pedagogy helped improve their understanding and skills in critical thinking, problem solving, conflict resolving, and leadership. Students reflected that this pedagogy helped improve professionalism, employability and made them more engaged and more connected with fellow students.

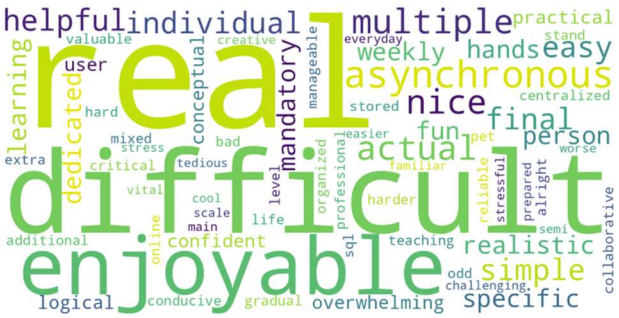

Figure 4. Word cloud plot of student reflection on their learning experience.

5.4 Sentiment analysis

We executed the same course overall survey of 5-point likert scale at the end of the semester in both sections. Students reflected on their learning experience. We mixed student responses from two sections, tokenized response text, extracted all meaningful words and created a word cloud plot (see Figure 4). Most frequent words in their

reflection are enjoyable, real, and difficult. It indicates that students like project-based learning. Though students in company-sponsored project performed better than student-selected project.

6. DISCUSSION AND CONCLUSION

Project-based learning is a popular form of active learning. There are many studies exploring project-based learning. Literature showed either student or company-sponsored project-based learning has its own advantages and disadvantages. But in literature, there are rarely studies of comparing these two types of project-based learning. This paper focuses on the comparative analysis. Authors conducted project-based learning in two online asynchronous database courses, one with student-selected form and the other with company-sponsored form. Student-selected project-based learning emphasized more on database development lifecycle and database design and implementation at a scale, for example, designing database from specifying their own requirements; company-sponsored project-based learning stressed database management, for example, security, back up and disaster recovery, and migration data from a plain text to database. Students meet company director for one hour bi-weekly. Although the intended database design was at a small scale in company-sponsored PBL, students were excited about the company collaboration, which motivated students well and facilitated promoting their learning. Our future work is to further learn the best practice to reduce potential risks in the early time of company-sponsored PBL, This paper set up a stage for us to design guidelines for better company-sponsored PBL.

Questions	T-test Statistic	P-value (T-test)	ANOVA F-value	P-value (ANOVA)	Levene's test	P-value (Levene ' test)	Effect Size
I think that working on the course project gave me the opportunity to improve my understanding about database design.	-2.846	**0.003**	8.097	**0.005**	1.027	0.312	-0.445
I think that working on the course project gave me the opportunity to improve my understanding in structured query language (SQL).	-2.953	**0.002**	8.721	**0.004**	0.54	0.463	-0.462
I think that working on the course project gave me the opportunity to improve my understanding in database implementation and optimization (for example, through the indexing).	-2.7	**0.004**	7.291	**0.008**	0.977	0.324	-0.423
I think that working on the course project gave me the opportunity to improve my understanding in database management (for example, security, backup, and recovery).	-0.672	0.251	0.451	0.503	0.025	0.874	-0.105
I think that working on the course project gave me the opportunity to develop professionalism.	-1.719	**0.044**	2.954	0.088	1.11	0.294	-0.269
I think that working on the course project gave me the opportunity to improve my critical thinking skills.	-2.113	**0.018**	4.463	**0.036**	2.426	0.121	-0.331
I think that working on the course project gave me the opportunity to improve my problem solving skills.	-3.242	**0.001**	10.512	**0.001**	0.231	0.631	-0.508
I think that working on the course project gave me the opportunity to improve my communication skills.	-0.71	0.239	0.504	0.479	0.032	0.859	-0.111
I think that working on the course project gave me the opportunity to improve my leadership development.	-2.137	**0.017**	4.567	**0.034**	0.924	0.338	-0.335
I think that working on the course project gave me the opportunity to improve my teamwork skills.	-1.375	0.086	1.891	0.171	0.033	0.856	-0.215
I think that working on the course project gave me the opportunity to improve my skills in conflict resolution.	-2.457	**0.008**	6.039	**0.015**	0.461	0.498	-0.385
I think that working on the course project helped connect my learning to future career goals.	-1.681	**0.047**	2.826	0.095	0.446	0.505	-0.263
I think that working on the course project facilitated the transition from post-secondary education to the workplace.	-1.789	**0.038**	3.201	0.075	2.244	0.136	-0.28
I think that working on the course project helped increase my ability to find a job post-graduation.	-1.189	0.118	1.415	0.236	1.954	0.164	-0.186
I think that working on the course project helped increase my employability.	-2.461	**0.007**	6.055	**0.015**	2.234	0.137	-0.385
I believe that working on the course project helped my career preparedness.	-2.834	**0.003**	8.033	**0.005**	7.338	0.007	-0.444
I believe that working on the course project helped me feel more engaged and connected to the course.	-2.271	**0.012**	5.157	**0.024**	7.818	0.006	-0.355
I believe that working on the course project helped me feel more connected to fellow learners	-2.515	**0.006**	6.324	**0.013**	4.948	0.028	-0.394
I believe that working on the course project helped me feel more confident to be connected to their future employer.	-1.956	**0.026**	3.826	0.052	0.163	0.687	-0.306
How likely do you want to recommend this type or mode of work-based learning experience to a friend?	-3.341	**0.001**	11.162	**0.001**	2.188	0.141	-0.523

Table 3. Course project feedback analysis. There are significant results for several feedback items, indicating that students in the student-selected section (052) felt less positive than the company-sponsored section (053).

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