Influence of Course Design on Student Engagement and Motivation in an Online Course

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ABSTRACT

We present a course design model for applying project-based learning to an online undergraduate object oriented systems course. In our model, projects and reflection are central to the curriculum. Our model challenges students through modularized, repetitive project cycles beginning with analysis and design (i.e. using pseudocode, flowcharts, diagrams) then coding, debugging, testing, and finally, reflection. We analyzed student reflection responses from two semesters to extract major themes and sub-themes, then mapped these to the MUSIC model (eMpowerment, Usefulness, Success, Interest, Caring) to understand our model's influence on student engagement and motivation. We found that a rhythmic project cycle encourages self-regulation in online students to formulate project plans, track their progress, and evaluate their solutions. Online students feel empowered when course projects promote choice, flexibility, creativity, experimentation, and extensions to other applications. Online student success is dependent on the clarity of instructions, course scaffolding, level of challenge, instructor feedback, and opportunities to reflect on personal failure, success, and challenge. Online students are interested in projects that are familiar, real-world, and fun, but expect to be situated in team-based environments. Students appreciate instructors who are caring and accommodating to personal needs. We recommend six salient strategies for improving online course and project design: design a visible, rhythmic structure; set transparent expectations and instructions; encourage design before implementation; connect to real-world applications and tools; experience happy challenges; infuse sustained reflection.

KEYWORDS

object oriented programming, student reflection, project-based learning, course design, real-world projects, student engagement, student motivation, online courses

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1 INTRODUCTION

Online courses are a mainstream in higher education. More instructors are having to redesign their face-to-face courses to teach online. The Inside Higher Ed survey shows that 9 out of 10 instructors (2018; N=2,129) were involved in online or hybrid course design and 25% of them worked with an instructional designer to improve the quality of their courses and to understand how to integrate available technology. Based on National Survey of Student Engagement (NSSE), Chen et al.[4] found a positive relationship between the use of learning technology, student engagement, and outcomes of learning.

Project Based Learning (PjBL) promotes learning engagement and motivation, particularly for students to apply technical knowledge, practice hands-on skills in programming, work in teams, and gain problem solving and project management abilities thru projects [14, 20, 26]. Engineering educators report on application of problem or project-based learning incorporated into classroom teaching [13, 20, 29, 30]. PjBL encourages students to solve real-life problems, making learning relevant, but also enables skill transfer to future professional careers [23, 29]. Additionally, Kayarvizhy et al.[20] emphasize the need for a well-defined course structure in PjBL courses, such as to include theory, lab, and a self study component. However, this structure is limited to courses that are classroom-based.

The research on PjBL in online computer science course design is scarce. Online courses, by default, are self-study; the implied classroom strategies of instructor lecture and project labs does not fit. This unique aspect forces instructors to rethink how to effectively implement PjBL in the online modality. Such instructors can benefit from nuanced research on PjBL models that facilitate effective project and course design for online learning in computer science.

2 RELATED WORK

2.1 Project-Based Learning (PjBL)

Several foci have emerged from the literature on PjBL that influence course design and project design:

Learning From Project Anchors. One foci of PjBL noted by Thomas [18] is that projects should be central to the curriculum rather than peripheral. Similarly, Espiritu et al. [9] state that projects should be intentionally designed as a "means for learning" than as a "means to assess learning". They observed that computer science instructors first covered a series of concepts and practice in early modules, then assigned a larger, take-home programming project at the end. The programming project was disconnected from earlier modules and students tend to resort to ad-hoc, trial and error approaches to complete the project. Projects should instead, serve as an anchor to guide the instructor's selection of learning objectives, conceptual knowledge, skills, and activities for each module [9, 12].

Learning Through a Self-Directed, Reflective Process. Another foci of PjBL is to involve students in constructive investigation [18]. Project work should be process-centered more so than product-centered [12, 29]. Course emphasis should be on the ability of students to apply a process of problem-solving repetitively throughout the course so they construct knowledge and gain practice to problem-solve. Process-centered learning facilitates the transferability of learned skills from one project to another; this can increase students' motivation to tackle new problems. However, Pucher et al. [26] caution that students are not experienced project managers and frequently run into problems in early phases of the projects. Thus, instructors should provide resources, scaffolding, collaborative team/peer support, and opportunities for reflection and revision [12].

Learning From Real-World Contexts. A third foci in PjBL is to design projects that are realistic, authentic, and real-world [9, 10, 18, 29]. Real-word projects are complex and may not have a single correct answer, but this makes the learning process authentic [7, 13]. Students also have varied perceptions on where project ideas originate, more so that their motivation, engagement, and achievement is greater when students suggest their own project ideas than when instructors predetermine or suggest projects [26].

2.2 Student Engagement and Motivation in Online Courses

PjBL has benefits to student learning such as increased engagement and motivation [13]. Student engagement refers to the extent of students' active involvement in activities, wherein student motivation represents the driving force behind students' involvement in activities [1]. Krause et al. [21] argue that student motivation as it relates to engagement depends on the relationship between the student and the learning environment. Coates et al. [5] suggest that engagement could change depending on the modality and design of the course.

Instructors have the initial responsibility to be intentional in designing online learning environments that offer engaging learning activities to motivate students [17]. Researchers affirm that interaction with content, peers, and the faculty promote student engagement and active learning online [6, 8, 22]. All three types of interaction are important for effective online learning, but students especially value student-faculty interaction [24]. Other critical aspects for success in online modalities is for faculty to (a) communicate (online and interpersonal); (b) use visual, auditory, and other multimedia tools; (c) maintain patience with students; (d) be flexible with course requirements, schedules, and communication modalities (Davidson, 2019). Student perceptions are subjective to their experiences and can vary across courses and between students [17]. Faculty members, however, believe the final responsibility for learning online lies with students [15, 21].

2.3 Conceptual Framework: MUSIC Model of Academic Motivation

Jones [16] developed the MUSIC Model of academic motivation with five strategies to effectively motivate students to engage in learning: eMpowerment, Usefulness, Success, Interest, and Caring. Faculty need to help students: (1) feel **empowered** by having the ability to make decisions on some aspects of their learning; (2) understand why what they are learning is **useful** for their short and long-term goals; (3) believe that they can **succeed** if they put forth the effort required; (4) are **interested** in the content and instructional activities; and (5) believe that others in the learning environment, such as the instructor and other students, **care** about their learning and about them as a person. This model aligns closely to the foci of PjBL and factors for student engagement and motivation discussed earlier.

3 RESEARCH QUESTION

Computer science faculty have a vested interest to design quality online courses that engage and motivate students. In this work, we explore course strategies that promote motivation and engagement for online learning environments [19]. The guiding research question for this study is as follows:

How does an intentional project-based learning course design model influence student engagement and motivation in an online computer science course?

4 METHODS

4.1 Course Redesign

ITCS 3112 is an undergraduate course in design and analysis of object oriented systems which students take in their junior or senior year. The course was taught as a project-oriented course, initially as a face-to-face course in Spring 2018, then redesigned as an online course in Summer 2018, adopting Quality Matters guidelines [27]. As of Spring 2019, the course was certified by Quality Matters. While the content of the course was retained, its structure was significantly modified. Each module is designed to follow the PjBL module structure in Fig. 2. Modules 1-6 have 2-week projects, while Module 7 is a 3-4 week term project. The online course was offered in Fall 2018 and Spring 2019. Note the primary researcher in this study was the faculty member for both semesters, while the secondary researcher in this study was the instructional designer who collaborated with the faculty member in the course redesign.

4.1.1 Content and Project Selection. Fig. 1 illustrates the seven modules of the course. The first three modules introduce the programming environment and the basics of C++: program structure, I/O, control structures and memory management. This is followed by modules on C++ classes, inheritance and polymorphism and object hierarchies. The final module brings the content from earlier modules together into an applied term project, implemented among groups of 2-3 students. Students are only provided guidelines for project topics, but choose their own project idea (within the scope of the course objectives). The final project spans 3-4 weeks with weekly reviews (two design reviews and an implementation review). The final project requirement includes turning in a complete design and description of the project and a demonstration of the project. The first 6 modules have the following project assignments:

- *Module 1:* To install the BRIDGES toolkit; to set up a VM and/or IDE; to draw a meaningful shape (a smiley face)

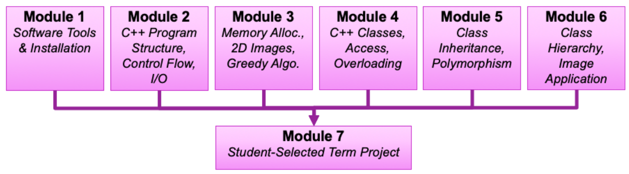

Figure 1: Content of the PjBL Online Course

- *Module 2:* To create a simple game application that uses control structures and I/O (e.g., Tic-Tac-Toe, Snakes and Ladders)
- *Module 3:* Mountain Paths, an adapted Nifty project to find a path from elevation data using a Greedy algorithm
- *Module 4:* To perform image processing operations such as image flipping, rgbToGrayscale, and color flattening
- *Module 5:* To create an interesting shape (face, car, etc.) using a shape hierarchy
- *Module 6:* Representing images using a 2D K-D Tree

Projects assignments used the BRIDGES toolkit[2, 28] to integrate engaging, real-world projects in the course. Since BRIDGES is implemented as an object oriented system, it provides an example of a real system for students (disseminated and used across multiple universities across the US). The course did not use a textbook, but an extensive set of links and references were provided.

4.1.2 Module Structure. Fig. 2 illustrates the structure of each course module. Each module required students to follow a repetitive cycle of steps:

- *Step 1 - Preparation:* Students begin with pre-reading and set up materials for the project. This step has a short 10-min multiple choice and problem solving quiz, auto graded for immediate feedback.
- *Step 2 - Problem Definition:* Students are given detailed descriptions of the project and tasks. Sample input data (if appropriate) and examples of expected output are provided.
- *Milestone 1:* The first deliverable in the 'think and design' phase, which encapsulates work from steps 1 and 2. Students are expected to create a plan and design the solution for the given problem. Expected outputs could be a flowchart, a diagram, or simply a list of functions, their relationships, and any needed data structures that will be used for implementation. These design artifacts are graded with feedback from the instructor or TA. Misconceptions are corrected and designs are revised prior to the next steps.
- *Step 3 - Problem Solving:* Students implement and document the project using their design from Milestone 1.
- *Step 4 - Test Solution:* Students test their solutions, making sure boundary cases are properly handled, and if appropriate, testing the implementation on additional data sets.
- *Milestone 2:* The second deliverable is the 'implement and code' phase). Students turn in a fully documented implementation of the project.
- *Step 5 - Reflection* Students complete a short reflection survey of their experience working on the module (as detailed in Section 4.2).

A discussion forum for each module is posed for Q&A among the students, the instructor, and the TA. Students are required to participate in at least 3 modules (both asking thoughtful questions and responding to other students' questions).

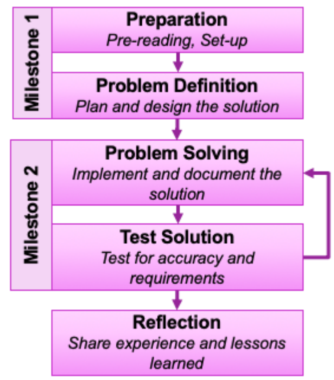

Figure 2: Module Structure and Sequence of the PjBL Online Course

4.2 Data Collection and Analysis

We gathered reflection surveys completed by students in each module. The reflection survey had a short answer question: *"What did you like and not like about the assignment?"* There were seven reflection surveys for Fall 2018 and seven more for Spring 2019. We collected 178 reflection responses (30, 24, 27, 27, 21, 26, 23) for Fall 2018, and 102 reflection responses (19, 18, 15, 17, 12, 13, 8) for Spring 2019. The responses to the short answer question were encoded as a sequence of textual statements and coded using constant comparison. The five categories from the MUSIC model (Empowerment, Usefulness, Success, Interest and Caring) were initial codes used to generate major and sub-themes. Keywords and short phrases were extracted representative of each theme and sub-theme. Most reflections corresponded to multiple categories and themes. Since the purpose of the reflection survey was to engage students in a self-assessment of their work and to provide feedback on each module, it was expected that we would see positive and negative responses. Thus, we tagged responses as positive or negative as we read through all reflection surveys. In all, there were 348 coded phrases across the two semesters of reflection surveys mapped to the five categories: Empowerment (42), Usefulness (25), Success (185), Interest (67), Caring (29).

4.3 Threats to Validity

The researchers applied triangulation and peer debriefing strategies. Both the primary researcher (i.e., the faculty on record) and secondary researcher (i.e., the instructional designer) independently analyzed the data and then came together to compare their findings, themes, and sub-themes to maintain consistency and reduce potential bias to one researcher's point of view. We each first coded four weeks of reflection surveys on Google Docs to develop a common code-book of themes and sub-themes. Two peer debriefing sessions were held between the researchers to discuss and compare emerging themes. Once we were both in agreement, we each coded the remaining three weeks of reflection survey separately and then came together for two more debriefing sessions. We each highlighted relevant keywords/phrases for each theme on Google Docs.

5 FINDINGS

Tables 1, 2, 3, 4, 5 illustrates the mapping of the reflection feedback to the MUSIC model's five categories, with the major themes and sub-themes stated, as well as representative quotes from the students, corresponding to each category of the MUSIC model.

Empowerment. Reflection responses relating to empowerment (42) were most evident modules 1 and 7 and to a lesser extent on modules 2, 3 and 5. Students enjoyed: the freedom to choose their own project group and topic for the term project, being creative with projects (e.g. drawing a face in Module 1), experimentation and tinkering with the code, and opportunities to extend projects beyond the requirements (e.g., adapting a game in Module 2 to other devices). These made project work an engaging and rewarding experience. Though there were a few students who preferred a more 'straightjacketed' approach to completing projects and some had difficulty finding suitable group partners.

Usefulness. Student reflection responses relating to usefulness (25) was the least reported (many overlapped with other categories such as Success and Interest). Students perceived projects as useful, such as working with real world tools, real world examples, and a real world team environment. For instance, students found the use of images (elevation data) for image processing (Module 4) and documentation tools such as Doxygen useful. Students also perceived that learning a lower level language like C++ will be useful for their career.

Success. This category garnered the largest response (185), surfacing from all modules for both semesters. Students attribute their success to: the quality and clarity of instructions in each module, challenge of assignments, module structure, and instructor feedback. Students used reflections to evaluate their personal successes, failures, and challenges. Technical issues with the BRIDGES server lead to student frustration, especially when close to deadlines. The repetitive project structure and clarity of instructions helped students complete projects. The level of the project difficulty correlated to student success, despite supports provided like detailed written instructions, the preparation and design phase, and sample outputs. However, students were motivated and engaged from the challenge of project (especially Module 3 onwards); many perceived challenge as positive in the sense that they like the balance between feeling challenged and feeling the satisfaction, confidence, and the rewarding experience of completing the project.

Interest. This category had 67 reflection responses. Modules involving games and visual images elicited positive reactions. Students were engaged in projects because they were familiar and fun. Using a familiar game (e.g., Tic-Tac-Toe, Snakes and Ladders) provides a low barrier of entry into the project. The interactivity, simplicity, and visual output (Module 1) that games afford were appreciated by students. Students also found interest in using real world images (e.g., elevation data in Module 3) coupled with a classic algorithmic strategy.

Caring. Reflection responses on caring (29) generated major themes relaying faculty were caring, considerate of student needs, and showed immediacy when responding to questions/concerns. For example, some students who had challenges balancing jobs and family required accommodation for more time and flexibility for assignments. Students expected timely feedback and looked to the faculty for addressing misconceptions. Several students reciprocated and showed their "care" by explicitly thanking the instructor in specific modules.

6 DISCUSSION

We recommend 6 salient strategies that influence course design and project design for promoting student engagement and motivation.

Visible Rhythmic Structure. A coherent course structure influences students' academic performance in an online course. A key aspect of our course redesign was to craft a visible, modular, and rhythmic structure across modules, scaffolded into milestones for preparation, problem definition, problem solving, solution testing, and reflection. The structure was presented as a visual map to students from the first module. The students found this consistent and repetitive structure instrumental to their success as they were able to start projects early, but more importantly, become self-directed to work through projects in a systematic manner. Students noted that this was something they had not done in previous coursework. Having a method to problem solving gives the students a life skill they can carry into their profession. Non-traditional or working students appreciated a well defined module structure allowing for a predictable set of activities that students could plan for.

Transparent Expectations and Instructions. Students are less impressed with "bells and whistles" and look for clear expectations and instructions in online courses. Examples of transparency include: clear course goals, detailed instructions, rubrics for assignments and grading, and samples of exemplary work [11, 25]. Students have increased confidence when they are explained the purpose of the course content and activities, tasks to complete (what to do and how to do), criteria for success (what does excellence look like, criteria to help students to self evaluate) [11, 25]. While these may have been typically demonstrated or explained by the instructor in the classroom, there is onus for the online instructor to make this same information explicit (in written, audio, or video format).

Design Before Coding. One of the key aspects of our PjBL module structure was to engage students to "design before coding". Design in programming courses is often assumed in student projects, but not explicitly expected or assessed. Expecting students to represent their design ideas in flowcharts, diagrams, or even simple lists forces them to think deeply about the problem and rationalize the options for solutions. A strong design could reduce time spend diagnosing errors during implementation.

Real World Projects and Tools. Students have better learning experiences when they gain valuable lessons for professional practice from working on a real project [23, 29]. Faculty need to be

Major Themes	Sub-Themes	Representative Quotes
Freedom to choose	Project and group choice	'liked..free-form nature of assignment', 'enjoyed doing it in groups', 'original program from scratch'
Flexibility	Completion time, open ended project design	'liked how open-ended it was'
Creativity and experimentation	Instructor didn't give everything away	'allows creativity in a way', 'experiment and messed around... while having fun', 'liked making the weird alien creature', 'able to be creative...so it could be unique'
Opportunity to extend learning	Go beyond requirements	'..plan to modify it to run on an Arduino', '..didn't give everything away', 'will probably try updating it', 'wide range of options that we can do'

Table 1: Empowerment: Themes and Sub-Themes

Major Themes	Sub-Themes	Representative Quotes
Real-world tools	Toolkit with real world examples, documentation tools used in commercial applications, working in teams	'excellent practical example of greedy algorithm', 'like learning about image processing', 'should prove useful in future assignments'

Table 2: Usefulness: Themes and Sub-Themes

Major Themes	Sub-Themes	Representative Quotes
Quality and clarity of instructions	Project dependencies, level of student competency, Need for more examples	'would have liked more instructions', 'steps were simple and straightforward', 'step by step process..helpful'
Course and module scaffolding	Repetitive cycle of steps, Immediate gratification - 'small wins', satisfaction after challenge	'module built off of of each other', 'liked the rhythm of the assignments','
Level of challenge	Student readiness, assignment pacing, individual success - from easy to difficult, more practice	'..challenging, but in a good way','challenged my..ability','felt..thrown in the module', '..feel I wasn't prepared enough..','..felt paced a lot better..'
Instructor feedback	Appreciation of prompt feedback	'forum was very helpful', 'follow through with questions from both professor and TAs were excellent..', 'getting feedback..was difficult'
Reflection on personal failure, success and challenge	Awareness of learning gaps, self efficacy/confidence	'At first..intimidated..feel challenged..also feel satisfied','not confident and proud of the work..', '..was difficult to complete but felt better about this one..','..job, class, personal life..wasn't able to devote as much time..'

Table 3: Success: Themes and Sub-Themes

Major Themes	Sub-Themes	Representative Quotes
Familiarity	Interested in project	'liked..this was an assignment I already had..'
Enjoyment	'Fun' factor (games, images)	'really enjoyed..eager to learn more', 'did not like..smiley face', 'enjoyed the assignment.. was engaging', '..nothing I didn't like', 'liked seeing visualizations', 'interesting way to incorporate a greedy algorithm','such a cool concept..while difficult, was fun'

Table 4: Interest: Themes and Sub-Themes

Major Themes	Sub-Themes	Representative Quotes
Consideration	Non-traditional student needs (accommodation), extra time	'parent, full time, very little time..keep quiz open for 2 days..', 'appreciated the extra time, 'appreciate the availability of the instructors and TAs', 'wish..the assignment was extended..'
Immediacy	Responding to student concerns, clarifying misconceptions, addressing technical concerns and student issues	'..appreciate these were clarified..discussion board.. making corrections due to these misunderstandings were distracting'
Appreciation	Thanking the instructor	'had compilation problems..thankfully the professor was able to resolve', 'Thank you for choosing this problem..I really learned a lot'

Table 5: Caring: Themes and Sub-Themes

intentional in selecting projects and resources relevant to student interests. In our study, students were engaged with projects that were familiar and fun, particularly games. Students also found interest in real world tools and technologies.

Happy Challenges. Students feel empowered when they are challenged to think, be creative, and construct their own ideas. While expectations and instructions are expected to be clearly defined, students prefer flexibility, freedom of choice, and time for experimentation when possible. We term these challenging projects as 'happy challenges' because students admit they had difficulty at first but satisfied with being able to 'figure it out'. Instructors must find the right balance on the level of difficulty for projects [3, 16] given the wide variability in skill levels in most CS courses. Faculty must also be caring and accommodating of student needs, capabilities and concerns.

Sustained Reflection. Adding reflection points at the end of each module encourages metacognition on personal failure, success, and challenge. Frequent reflection allows students to be aware and evaluative of *what they are learning* and *how they are learning*. This approach also increases the one-to-one relationship between the students and the instructor, knowing they can air out difficulties, be honest in their progress, vent on negative experiences, and boast on positive experiences. The instructor then, can provide specific support to each student based on their reflection responses.

7 CONCLUSION

Online teaching is challenging, but online learning is more challenging. We embarked on a course redesign to provide students a high quality and engaging student learning experience applying a PjBL model where projects and student reflection were central to the curriculum. We analyzed student reflection data to extract major themes and sub-themes aligned to the MUSIC Model to understand how our course design influenced student engagement and motivation. This study found evidence of all five categories (eMpowerment, Usefulness, Success, Interest, Caring) in our course design model, as reported in student reflection responses. The course/module structure, content scope, project design, assessment design, instructional resources and tools are critical factors to providing students an engaging learning environment that motivates them to learn online. Our course design model can be replicated to fit almost any skill-based or project-based online module, but must be carefully planned and be intentional to student learning outcomes.

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