Problem-based Learning (PBL) in Interactive Design: A Case Study of Escape the Room Puzzle Design

Ping-Yeh Li[1,a] ; Ya-Kuan Chou[2,b] ; Yun-Ju Chen[3,c] ; Ruey-Sen Chiu [4,d*]

[1]Department of Interactive Entertainment Design, China University of Technology; Hsinchu Campus: No. 530, Sec. 3, Zhongshan Rd., Hukou Township, Hsinchu County 303, Taiwan, R.O.C.

[2] Department of Interior Design, China University of Technology; Hsinchu Campus: No. 530, Sec. 3, Zhongshan Rd., Hukou Township, Hsinchu County 303, Taiwan, R.O.C.

[3]Department of Interactive Entertainment Design, China University of Technology; Hsinchu Campus: No. 530, Sec. 3, Zhongshan Rd., Hukou Township, Hsinchu County 303, Taiwan, R.O.C.

[4] *(Corresponding Author) Department of Interior Design, China University of Technology; Hsinchu Campus: No. 530, Sec. 3, Zhongshan Rd., Hukou Township, Hsinchu County 303, Taiwan, R.O.C.

[a] pingyehli@gmail.com, [b] miaululumi@yahoo.com.tw, [c]yjchen@cute.edu.tw, [d]rdesignchiu@yahoo.com.tw

Abstract

As an experimental research carried out to document, discuss and reflect on the problem-based learning (PBL) in emerging "Maker" courses, this study investigates a case study of "Escape the Room" Puzzle Design in a University of Technology in Taiwan. Twenty-six first-year university students have participated in this experimental research. The paper discusses the practice of PBL and related obstacles in interactive-design-learning. This study suggests the co-relation between PBL's outcomes with the number of group members, students' skill of collaboration and difficulty of tasks.

Key words: PBL, problem-based learning, interactive design, escape the room

Introduction

Most design curriculums were guided by "structured problem", in which the students learned by analyzing an objective and pursuing a specific target. Such a curriculum begins with an "end product" or "artifact" in mind. However, "structured problems" often do not transfer to real-life, fail to provide students with meaningful learning opportunities [1], and negatively impact student motivation [2]. In recent studies, researchers tend to achieve learning through "ill-structured problem" by including other strategies, such as Design Thinking as part of the curriculum. For example, Design Thinking often encourages the students to collaborate with inter-disciplinary knowledge, and re-consider their design target through practice. Researchers also suggest classes that deal with process or product design and development are "well-suited" for hybrid-problem and project-based learning opportunities [3, p. 22], which ultimately enhances motivation by allowing "every student to experience success" [4, p. 44].

Similar to various professions such as engineering or architecture involving "complex and ill-structured design problems" [5], the interactive design projects conducted in this research also aimed to provide students with opportunities to solve meaningful problems. In other words, the design problem was in the center of the focus which fosters a process among the students of assessing and discussing the issues of the problem. The goal was to activate the prior knowledge of making and reconstruct them in a design process. In addition, by controlling several factors, this study intended to understand how future students may optimize their study in ill-structured design tasks.

This problem-based learning (PBL) research was conducted in the Maker Laboratory of Department of Interactive Entertainment Design (IED), China University of Technology in Hsinchu County, Taiwan. "Escape the Room" was the final project for the first-year students in the second semester in 2017. The students are divided into four groups. Each of the student groups has developed a unique background story and brought in unique design target and problems. The students have developed basic interactive design skills in previous semester. However, in order to solve the problems in Escape the Room project, it was necessary to re-assemble their prior knowledge. This condition corresponds to several prerequisites in problem-based learning (PBL), such as self-directed learning, working cooperatively, student-centered study and interdisciplinary learning process.

Scenario

The scenario of this curriculum is to enhance the students' programming, digital making and information collecting skills by interactive mechanism design. By facilitating Maker tools in hands-on practice, the students also develop their creativity and problem-solving ability. To ensure the learning objectives were met, this research integrated the curriculum by the following seven steps. This is a simplified version of Maurer and Neuhold's [6] seven-steps of PBL. These steps have a rather stronger focus on hands-on practice by which the students were anticipated to learn from experimenting and realizing their own design idea through the process:

A. Clarifying Terms and Concepts.
B. Formulation of Problem.
C. Brainstorming.
D. Structuring and Hypothesis.
E. Formulation of Objectives.
F. Self-study.
G. Post-discussion and Self-assessment.

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Methodology: A Quasi-Experiment

It became necessary to implement a quasi-experimental research to observe the main elements that might influence student learning. This study mainly looked at the 'number of group members', 'difficulty of tasks', and 'skill of collaboration' as key factors. In order to control other factors, all the students were provided with equivalent Maker facilities (3D printer, laser cutter and etc.), spatial condition (a 200cm*130cm working table, and other laboratory space), and time (one semester). The key factors are explained as follow:

A. Number of Group Members

Twenty-six first-year university students were observed in this study. They were separated into four groups by Professor Chiu in her curriculum. The numbers of group members were respectively 8, 3, 8 and 7 students. The student groups followed their own story background, and self-led to different kind of tasks.

B. Difficulty of Tasks

This research identified its problem difficulties based on Jonassen and Hung [5]'s research. Jonassen and Hung articulate a model for evaluating problem difficulty in terms of 'complexity', including breadth of knowledge, attainment level, intricacy of procedures, relational complexity, and problem 'structuredness', including intransparency, heterogeneity of interpretations, interdisciplinarity, dynamicity, or competing alternatives. Based on these characteristics, we thus identified four classes of difficulties in this research. The assessment of these difficulties was made after the students' projects were accomplished.

C. Skill of Collaboration

In order to assess the students' skill of collaboration, this research observed the student group's way of discussion, the key for decision making, interaction with the tutors, division of assignments, and overall participation.

Observation

The four groups were observed and documented during the design process. In order to compare and analyze different skills and activities by a quantitative result, the tutors assessed the following abilities with different grades by: 1 (Bad), 2 (Acceptable), 3 (Good), 4 (Very Good), and provided the main reason (Why). This research's observation was documented as follow:

A. Group A:
(1) Number of group members: 8.
(2) Topic: Puzzle and Key-drop Mechanism.
(3) Self-defined Problem: A mechanism for dropping the key after the puzzle is done by the players.
(4) Documentation of Work: 3 (Good).
(5) Difficulty of Tasks: 2 (Acceptable). This task includes color sensor data processing and servo motor control. It also facilitates digital fabrication skills for making a user-friendly puzzle mechanism. However, this is a rather simple input-output system.
(6) Students' Collaborative Skills: 2 (Acceptable). Plenty members, longer discussion, not easy to find a direction. Sometimes seek the tutor's help to reach consensus.
(7) Division of Assignments: 2 (Acceptable). Two students learn Arduino circuit and coding, two make the wooden structure, two handle puzzle piece making. Two of them show less participation.
(8) Player-feedback: 4 (Very Good). Very simple user interface. Easy to play with. Easy to understand.
(9) Progress Making: 2 (Acceptable). Need tutor's instruction but complete on time.
(10) Location of Necessary Information: 3 (Good). Usually find necessary information by themselves.
(11) Self-tracking of Errors: 4 (Very Good).
(12) Self-reflection: 3 (Good).
(13) Deeper content understanding: 2 (Acceptable). Generally understand the content well.
(14) Total points (Overall Assessment): 27.

Fig. 1 Design Work by Group A

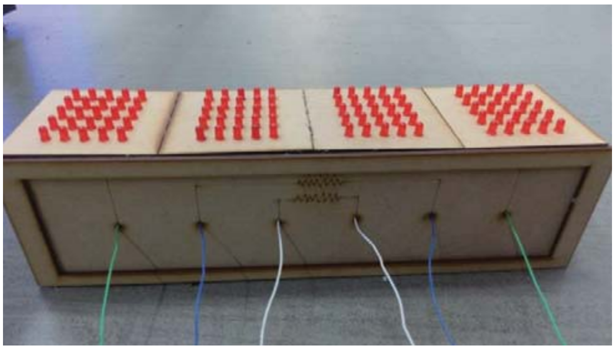

Fig. 2 Design Work by Group B

B. Group B:
(1) Number of group members: 3.
(2) Topic: Current Transmit Mechanism.
(3) Self-defined Problem: A mechanism for the players to connect circuit in different ways. If the circuit is correctly done, it shows the password.
(4) Documentation of Work: 2 (Acceptable).
(5) Difficulty of Tasks: 3 (Hard). This task needs to apply the 'analogWrite' command to generate different current output on the Arduino digital pins, and uses the analog pins to detect the readings. It includes coding skills for averaging the received data. It also requires multiple LEDs to show the password.
(6) Students' Collaborative Skills: 4 (Very Good). Few members, easy and quick discussion, most decisions are made

by all three students. Self-testing and experimenting before seeking tutor's help.
(7) Division of Assignments: 4 (Very Good). One student learns Arduino circuit and coding, one collects materials, and one does the hand-on making. Discuss when confront a problem. Each member has good participation.
(8) Player-feedback: 2 (Acceptable). Hard to understand. Need to provide more information for the players.
(9) Progress Making: 3 (Good). Complete on time.
(10) Location of Necessary Information: 4 (Very Good). Mostly find necessary information by themselves.
(11) Self-tracking of Errors: 3 (Good).
(12) Self-reflection: 3 (Good).
(13) Deeper content understanding: 3 (Good). Deal with hard tasks and understand content well.
(14) Total points (Overall Assessment): 30.


Fig. 3 Design Work by Group C

C. Group C:
(1) Number of group members: 8.
(2) Topic: Three Knobs Password Mechanism.
(3) Self-defined Problem: A mechanism for the players to turn three knobs. If the knobs are correctly turned, the alarm system will turn off. The players can safely walk out the room.
(4) Documentation of Work: 4 (Very Good).
(5) Difficulty of Tasks: 4 (Very Hard). This task needs to use LEDs and light-dependent resistors to detect whether the knobs are correctly turned. The interface is then integrated with an alarm system made by an ultrasonic distance sensor and a buzzer. The students have to integrate a breadth of knowledge to achieve the result.
(6) Students' Collaborative Skills: 3 (Good). Plenty members, long discussion. Two of the students mainly guide the whole group. Sometimes seek the tutor's help to reach consensus. Generally showing good communication skills.
(7) Division of Assignments: 3 (Good). Good division of assignments: Two student learns Arduino circuit and coding, one makes the structure, one does the documentation, and one does the presentation. However, few of them show less participation.
(8) Player-feedback: 3 (Good). Simple user interface. Highly finished work. Provide good player experience.
(9) Progress Making: 4 (Very Good). Deal with complex tasks and complete on time.
(10) Location of Necessary Information: 2 (Acceptable). The tutor helped provide some necessary information.
(11) Self-tracking of Errors: 2 (Acceptable).
(12) Self-reflection: 4 (Very Good).
(13) Deeper content understanding: 4 (Very Good). Deal with very complex tasks, show good content understanding and made good progress.
(14) Total points (Overall Assessment): 33.

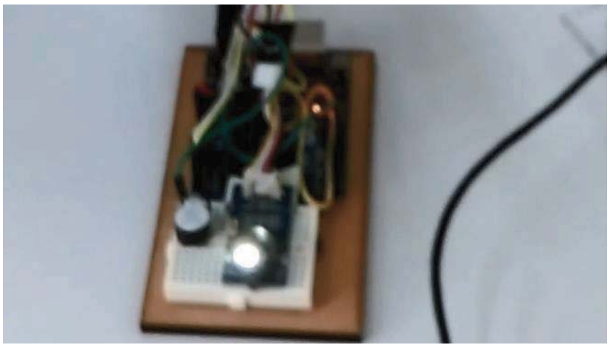
Fig. 4 Design Work by Group D

D. Group D:
(1) Number of group members: 7.
(2) Topic: Color Detect Mechanism.
(3) Self-defined Problem: A mechanism for the players to scan the object's color. If the color is wrong, the alarm starts.
(4) Documentation of Work: 1 (Bad).
(5) Difficulty of Tasks: 1 (Easy). This task is a simple input-output system. The students can mostly achieve the result by downloading example code online.
(6) Students' Collaborative Skills: 1 (Bad). Plenty members, longer discussion, not easy to find a direction. The tutor has to help and engage to reach a decision.
(7) Division of Assignments: 1 (Bad). Bad division of assignments: No division of work before the tutor reminds them to. The prototyping materials are not prepared until the end of semester. Most of the works are done by two of the members.
(8) Player-feedback: 1 (Bad). Less connection with their story background.
(9) Progress Making: 1 (Bad). Need tutor's instruction most of the time. Barely finished the tasks.
(10) Location of Necessary Information: 1 (Bad). Need tutor's instruction most of the time.
(11) Self-tracking of Errors: 1 (Bad).
(12) Self-reflection: 1 (Bad).
(13) Deeper content understanding: 1 (Bad). Dealt with rather easy tasks. Showed less understanding of tasks.
(14) Total points (Overall Assessment):10.

Analysis and Results

A. Number of Group Members

In this study, groups with more than 5 students seemed hard to reach consensus when facing choices. Group B (with 3 students) showed better collaborative skills and solved problems more efficiently. Otherwise, Group A, C and D seemed hard to make critical decisions. The tutor had to engage often to help reach an agreement. It was also quite often that members in big groups do not agree on the decision made by other group members. As Interaction Design is a profession toward better user experience, there are a wide range of possibilities in the design process. It is also very common that the designers change the design concepts in the process of

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making. Practical hand-on testing of prototypes should be encouraged, and decision-making through merely discussions should sometimes be prevented in specific sequences. In other words, “making” is considered more critical than “discussing” in a sense. How to effectively reach a decision and start prototyping is essential in PBL in Interaction Design. This research suggests that a design group with 3-4 members should perform better communication and concentration.

TABLE I
Analysis of Students’ Learning Progress

	Group A	Group B	Group C	Group D
Group members	8	3	8	7
Difficulty of Tasks	2 (Acceptable)	3 (Hard)	4 (Very Hard)	1 (Easy)
Overall Score	27	30	33	10

B. Difficulty of Tasks

According to TABLE I, the difficulty of tasks does not show direct relevance with the number of group members. Small group (Group B) and large group (Group C) can both accomplish difficult tasks. In addition, tasks with high complexity caused the students to change direction or method often. For example, the complex self-defined problem of Group C showed many competing alternatives along the process. The tutor played an important role to assist the students to clearly formulate their problems, and execute a well-structured practice and self-study.

On the other hand, both groups dealt with high difficulty (Group B and C) accomplished the project successfully. Interaction Design tasks with high complexity seemed to stimulate the students to learn in depth. For example, the problems solved by Group C could be decomposed into ‘user interface design’, ’electronic mechanism design’, ‘buzzer alarm system’, and ‘atmospheric design’ of the space. This required the students to explore, learn new skills and integrate a variety of knowledge. Students in Group C apparently showed self-confidence and feeling of accomplishment in their final presentation and video documentation. Evidently, higher difficulty of tasks stimulates the students to learn and explore.

On the other hand, tasks with low complexity can only drive the students to solve simple layered problems. In the final presentation, students in Group D showed less confidence and organization.

C. Skill of Collaboration

As the above observation shows, skill of collaboration should include: interaction with the tutor, division of assignments, progress making, location of necessary information, self-tracking of errors, and self-reflection. In this study, Group B has the least members but performs the best communication efficiency. The collaboration in Group B showed that the skills of “making” were as important as (or even more important than) the skills of “communication”. Therefore, this research suggests the tutors in Interaction Design curriculum to encourage the students to “discuss through making”.

Furthermore, the player-feedback on the final design work (the Escape the Room Game) does not show direct relevance with the overall assessment of student learning. Group A only ranked No.3 in the overall score but got the best player-feedback. The main reason was Group A’s design was easy-to-play and easy-to-understand. This suggests that an interactive mechanism design should seek playfulness and simplicity, even the process of making very likely contains much struggle and complexity. It shows a challenge considering how to balance the process-oriented PBL curriculum with good product-oriented outcomes.

Conclusions

The study applies problem-based learning (PBL) in an Escape the Room design activity. By the above observation and analysis, this paper suggests:

A. Challenge the Students

Difficult tasks in this study stimulate the students to learn in depth. Student-designers who deal with complex tasks tend to accomplish good results. This study encourages the tutors of PBL in interactive design to guide the students into challenges and hard tasks through the design process.

B. Group with 3 to 4 Members Performs Best Collaboration

Best number of group members is 3-4 students. This facilitates communication and concentration.

C. Find Balance between the Process-oriented and Product-oriented Outcome

PBL encourages the students to learn in depth and in complexity. However, an interactive design work requires simplification and playfulness. How to balance the process-oriented PBL curriculum with good product-oriented outcomes suggests good direction for future research in interaction design curriculum.

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