Developing a Creativity-enhanced PBL for Inspiring Future Hydraulic Engineers

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INTRODUCTION

Taiwan is in a seismically active zone and frequently experiences tropical storms and large variations in precipitation. Water resource management has been a critical issue and water storage in dams and reservoirs takes a great share in Taiwan. Due to the lack of desirable dam sites, the reduction of sediment deposit in reservoirs has become received increasing attention [1]. Sediment trapped behind dams reduces reservoir capacity. In some cases, reservoirs have filled with sediment, impairing their functionality or, in serious cases, rendering the dam infrastructure useless and posing safety hazards (Wang and Kondolf, 2013) [2]. Sumi et al. (2004) reported that global gross storage capacity was about 6000 km3 and, with annual reservoir sedimentation rates of approximately 31 km3 (0.52%), global reservoir storage would be cut in half by the year 2100 [3]. Annandale (2013) estimated that global net reservoir storage has been declining from its peak of 4200 km3 in 1995 because the rate of sedimentation exceeds the construction of new storage [4]. With increasing demands for water storage and fewer feasible and economically justifiable sites available for new reservoirs, loss of capacity in our existing reservoirs threatens the sustainability of the water supply (Annandale 2013). While some dams can be designed to pass sediment, either through the dam or around the reservoir, using a range of proven techniques, each potential solution is subject to a range of conditions. Furthermore, sediment management approaches are not used in many reservoirs where they could be. It may be that dam developers and operators are not aware of the range of potential management approaches and the fact that they have been demonstrated to be effective. It thus highlights the importance of managing the consequences of reservoir sedimentation and, at the same time, directing hydraulic engineering education towards practical and relevant learning while also fostering higher order thinking skills, such as creativity and problem solving.

As sediment accumulates behind dams, it can impair reservoir functions and ultimately reduce or eliminate storage capacity, threatening the sustainability of water supply and hydroelectric generation. In Taiwan, the sediment-plagued Tsenwen

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Reservoir is one of the many dams planned and built without any consideration of sedimentation. At 133 m high, Tsenwen Reservoir is the largest reservoir in Taiwan, supplying water for irrigation, as well as secondarily meeting municipal and industrial demands. About 90% of the annual rainfall is concentrated in the wet season from May through October, and only 10% is distributed throughout the rest of the year. The accumulative sedimentation from its completion in 1973 to 2008 was 160 million m3 with annual sedimentation rate of 4.65 million m3. In August 2009, typhoon Morakot caused reservoir sedimentation of about 91 million m3 in this single event, increasing the annual sedimentation rate. To manage the high sediment loads to the reservoir, different efforts and budget were spent on construction of upstream check dams, hillside erosion control measures, hydrosuction, and mechanical removal. While the efficiency of above-mentioned measures is limited, the Water Resources Agency in Taiwan has been conducting an assessment of options to improve sediment management. The Tsenwen dam is now retrofit with a sediment pass-through tunnel to vent turbidity currents.

Since project-based learning (PBL) provides contextualized and authentic learning, which has been demonstrated to foster higher order thinking while promoting acquisition of content-area knowledge, this project applies PBL to hydraulic engineering education. A PBL curriculum was designed to expose students to real-world problems, deepen their academic knowledge while exploring, and further enhance students' learning motivation, learning emotion and performance, and 21 century skills [5]. For college education, courses that require great amounts of hands-on experience extensively adopt PBL to cement students' practical use of knowledge. However, to better prepare students for the future challenges, traditional PBL can be enhanced by specifically integrating 21 century skills. To serve this purpose, this study adopted Creativity-enhanced PBL, emphasizing the training and development of creative thinking, and using a real world issue －reservoir sedimentation－to foster problem solving (PS) skills [6]. The goal of fostering creativity in instruction is to promote divergent thinking [7] and to guide students to develop the ability and intention to develop innovative solutions to problems.

THE STUDY

This study adopted a pretest and posttest quasi-experimental design. The research design is illustrated in *Figure 1*. The independent variable was instructional strategy, either Creativity-Enhanced PBL (the experimental group) or traditional PBL instruction (the control group). The dependent variables were students' hydraulic engineering knowledge, problem solving, creative thinking, learning motivation.

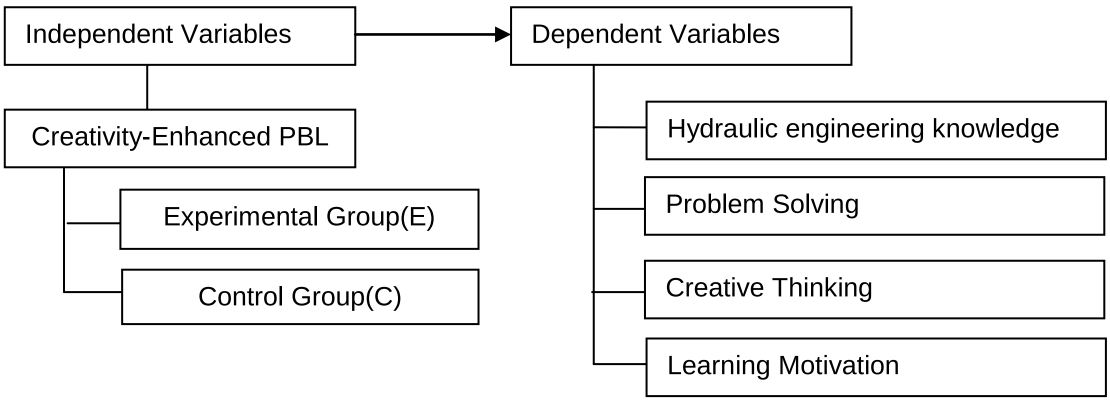

Fig. 1 Research design

1. PARTICIPANTS

Participants for this study were recruited from the Hydraulic Engineering department of a large university in Taiwan. Fifty-five students registering for the course "seminar" were free to choose between two groups. Thus, thirty students were in control group (C) receiving traditional PBL instruction and twenty-five in the experimental group (E) receiving creativity-enhanced PBL.

2. RESEARCH PROCEDURES

Two kinds of course styles alternated in this course. Every two weeks, the lecturer met with students once to teach a 50-minute lecture. The other week, students decided to meet with their group members for independent studies. The duration of the experiment was sixteen weeks, over the course of two semesters. Four tests were given as pretests, including a hydraulic engineering knowledge test, the Abbreviated Torrance Test for Adults (ATTA), Creative Problem Solving Test (CPST), and Motivated Strategies for Learning Questionnaire (MSLQ).

The course was designed to emphasize the real-world reservoir sedimentation problem using Tsenwen reservoir as a case study through in-class lectures, field studies, and laboratory experiments. In-class lectures included topics such as watershed sediment, reservoir sedimentation, and desilting strategies, covering professional knowledge required for hydraulic engineering students to understand the reservoir sedimentation issue. Field studies were designed for the students to understand practical on-site issues, while laboratory experiments were aimed at illustrating the mechanisms of one of the desilting strategies, i.e. the venting density current.

During the first two weeks of the course, both research groups attended classes together to take the pretests and receive an introduction to the curriculum. Beginning at the third week, the course proceeded with lectures covering basic knowledge of reservoir sedimentation, such as sources of sediment and criteria of the motion of initiation. For the fifth and sixth week, the problem context was introduced to both groups: How to relieve Tsenwen reservoir sedimentation by eighty percent.

At this point the instructional strategies for the two groups diverged. For the control group (C), the lecturer adopted traditional PBL by leading group discussion sessions about suspended load, bedload, and trap efficiency; for the experimental group (E), creativity-enhanced PBL was augmented with a group brainstorming activity—card exchange. In a group of five, one student, based on the problem the lecturer gave, noted down his/her idea on a card with a blue pen, then passed the card to the group member on the right and continued to add more thoughts on the card. If the member has any idea similar to the previous ones, he/she could use a red pen to add more concrete and specific thought on the card. In the end of the class, the lecturer shared all the ideas with the class by projecting the cards from every group on the screen. After class, students discussed ideas on the card they wrote in class in the time for independent study, use a mind map to reorganize their brainstorming.

For creativity-enhanced PBL, the lecturer provided a real world problem related to hydraulic engineering, assisted with proper creative thinking skills and a web quest. All the group members worked together to decide the cause of the problem, think up possible solutions and revise the solution based on feedback. In class, in addition to

Table 1. Summary of the two research groups including time allocated for learning tasks

Instructional Activities	Comparison Group: Project-based Learning	Experimental Group: Creativity-enhanced PBL
Content delivery	PPT-assisted instruction (30%)	PPT-assisted instruction (10%)
Group Discussion	Group Discussion and Class Presentation (15%)	Creative thinking group discussion and Class Presentation (15%)
		Teacher Feedback (5%)
Creative thinking and Problem solving tasks		Creative thinking and problem solving integrated training (15%)
Outside the classroom activities	Field trip (5%)	Field trip (5%)
	Independent study (40%)	Independent study (40%)
Assessment	Project Presentation (10%)	Project Presentation (10%)

direct instruction of hydraulic engineering course content, the lecturer provided students with creative thinking skills and group discussion guidance as scaffolding;

outside of class (every other week) students met in groups to gather the information needed for class discussion time. The activities in group (E) were shown in *Table 1*.

3. DATA ANALYSES

Both quantitative and qualitative data will be collected for this study. Descriptive statistics will be used to describe the means, standard deviations, and adjusted means for the tests between the two groups. Next, analysis of covariance (ANCOVA) will be used to compare the final results of the two research groups after 18 weeks of instruction, with pretest scores as covariates to eliminate the effect of any existing pretest differences on the results. From a qualitative perspective, data will be collected from feedback forms during the last week of class, through which we know students' acceptance of teaching strategies and improvement students thought we can make.

DISCUSSION

At the end of this study, five respective descriptive statistics from experimental group and control group will be received. With the statistics, contrasts between pretest and posttest as well as the between-group comparison can be made. Therefore, some assumption can be proven according to these data.

1) Given that both groups used the same teaching material, the contrast between pretest and posttest from both groups can tell the content validity of teaching material.

2) Receiving PBL instruction on the same project, both groups will therefore make improvement in hydraulic engineering knowledge.

3) Because the two groups adopted different teaching strategies, the contrast can be made by comparing the posttest results to see whether creativity-enhanced PBL can help students deepen their knowledge on hydraulic engineering and, at the same time, achieve higher regarding problem- solving skills and creative thinking skills.

4) By involving creative thinking skills in PBL instruction, students' academic achievement in hydraulic engineering knowledge, along with their learning motivation can be effectively improved. With such result, this research can be expanded and further analysis can be done. Hopefully, this creativity-enhanced PBL can make contribution and be extensively applied in courses in College of Engineering. We expect students to be active and efficient learners whose potentials can be fully discovered because of this intriguing and inspiring teaching strategy.

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