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A Special Approach to Teach Artificial Intelligence*

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Problem-Based Learning (PBL) is a promising and student-centered teaching method. This paper discusses the methodology and its application to teach Artificial Intelligence (AI) in detail. Also, it aims to construct a web- and problem-based (PBL) system for students at the department of computer science and information engineering. The central bases on the instructional theory, learning theory, and PBL activities are applied to this paper. Given this, the authors intend to educate students with team working, data analyzing, and problem-solving capabilities. The learning experiences in the two course forms including the PBL approach and the traditional one are compared by using a questionnaire response and examination scores. Moreover, the ability of technological innovation can enable students to enhance their competencies. The research results obviously show that the PBL approach can help students learn more about Artificial Intelligence (AI). Additionally, in the PBL course with an interaction in small groups, students learn how to present what they thought, how to clarify and define what a problem is, and how to precisely grasp what the relevant information is.

Keywords: Artificial intelligence (AI); problem-based learning (PBL); web-based instruction system

1. INTRODUCTION

PROBLEM-BASED LEARNING (PBL) is a learning process in which the teacher assigns a problem to students and lets them self-study at the very beginning. Then students join their own group discussion and talk about the possible solutions to the problem with the teacher. Finally, each group exchanges knowledge with one another and finds the optimum solution to the problem.

The PBL approach originated from McMaster University in 1960. It implies that a learning method associates with the constructivism implemented in the real world [1]. Currently, we are staying in the era of knowledge economic advancement, information technology, and rapid social changes. In order to face the new challenges of knowledge economy, the traditional teaching and learning methods are insufficient to meet the needs of educating talented people in the new era. Contemporary society has evolved to be a continuously learning one. Only the lifelong learning people can survive in the world [2–4]. Consequently, the concept of how to survive has been proposed by the association of education and science in the United Nations and a global education revolution seems to occur [5–6]. Therefore, the Hong Kong educational institute proposed such a slogan, lifelong learning and all human beings learning, and the curriculum development conference selected how to effectively learn something as one major theme [7–8].

The PBL approach means that the teacher chooses a practical problem as the core of a teaching process and encourages students to carry out a group discussion. This teaching process can educate students to learn actively, to think critically, and to solve problems correctly [9]. In order to make students become active learners and know how to learn, students must understand where the problem is. They should keep questioning and try to obtain domain knowledge by clarifying a huge amount of information. The PBL approach is interpreted as the blueprints of constructivism and emphasizes that students must insight on one verifiable prediction [10]. Therefore, students can obtain capabilities of thinking critically and creatively. In the future learning society, students must learn how to survive, how to learn, and how to live in the society of knowledge economics based on the concepts of all human beings thinking and lifelong learning.

The issue of web-based instruction has been broadly discussed in recent research. A lot of important teaching and learning variables in the web-based instruction have been systematically investigated. Those studied variables contain web presentation formats, courseware design, student

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learning styles, etc. [11]. The web-based PBL system is actually a platform and forum provided to students participating in learning and discussing activities. Meanwhile, the existing problem in AI teaching and learning is that those AI problems are more verbal and algorithmic. Thus it is hard to teach for teachers and is hard to learn for students. This motivates us to propose the web-based PBL system.

Based on the above research motivation, the purposes of this paper are:

1. to organize a web-based teaching activity for AI at the technological university level [12];
2. to construct a web-based PBL system for AI [13].

2. THE TRADITIONAL COURSE AND ITS CONTENTS

Artificial Intelligence (AI) is taught in two one-semester courses to third-year students enrolled in the Department of Computer Science and Information Engineering (CSIE). Course AI 1 is mandatory for CSIE students and has over 46 participants annually. However, course AI 2 is selective, causing the participant number to decrease to around 30. Each of the two courses has 36 hours of lectures and 18 hours of tutorials, with a 2-h lecture and a 1-h tutorial each week. Both lectures and tutorials are voluntary.

Course AI 1 covers those topics including search and problem solving, reasoning and production system, expert systems and knowledge engineering, uncertainty, probabilistic reasoning and fuzzy logic, AI programming languages, knowledge representation, and natural language understanding. Discrete mathematics is also used wherever necessary.

Course AI 2 progresses in those topics including cognition, machine learning, robotics, speech recognition, neural networks, interface and information agents, and multi-agent. More advanced algorithms are covered wherever convenient.

Mastering AI requires a certain degree of practice. We must keep the idea of how, what, and even why some algorithm needs to be analyzed and calculated, and yet be adept in complexity manipulation. Usually, the burden of complexity manipulation causes the student to lose sight of learning objectives. The only key answer to this conundrum is practice. In the tutorial session or at home, the students are assigned three weekly problems to be solved. In addition, a homework problem is assigned each week, which is graded, if returned. The total homework grade is scaled so that the maximum is 15% of the examination, and then it is added to the examination grade only if a passing grade (60%) is reached. Therefore, the student can increase his/her grade by one if obtaining a sufficient score from the homework assignments.

Passing the course requires obtaining at least 60% of the score in either one midterm or one final examination, each including the solving of five problems. The grading system is shown as follows: 0 = Fail (0%–49%), 1 = Pass (50%–59%), 2 = Satisfactory (60%–69%), 3 = Good (70%–79%), 4 = Very good (80%–89%), 5 = Excellent (90%–100%) [13].

3. THE PBL METHODOLOGY

3.1 The PBL core

The core of the PBL approach lies in using the following seven steps [14], according to the Maastricht model, listed herein for convenience.

1. Clarifying terms: Well-known terms, whose meanings are unclear, and unknown terms are clarified, if necessary, by the tutor.
2. Defining the problem: The students define the issues captured by the problem.
3. Analyzing the problem: The students brainstorm and list as many connections, explanations, and hypotheses as they can for the problem. This step activates any prior knowledge within the group.
4. Systematic clarification: The listed explanations and aspects that emerge in the brainstorming are linked and classified into higher-level groups with the defined problem in mind. These links are not always correct.
5. Formulating learning objectives: Well-defined and concrete learning objectives are set to obtain additional information based on the knowledge acquired.
6. Self-study: The student finds out keywords, reads all the relevant materials and sources, and collects at least the information required for the learning objectives.
7. Reporting: Sharing with other group members the results of one's inquiry is needed.

Based on previous motivation and purposes, this paper investigates the applicability of PBL to Artificial Intelligence taught in National Formosa University. The learning process is carried out on the basis of learning theory, organized as a teaching activity of PBL. By using a teacher's observations, student interviews, and analysis of the related literature, the learning process is gradually recalled and improved. This approach can guide the students to learn AI [15–17] and keep finding out related problems, defining them, obtaining the problem-solving methods, and solving the problem. Thus the PBL model is finally formed.

The analytical approach to data is mainly based on the quantitative and qualitative research method. By using the design and implementation of PBL, a suitable teaching model is constructed for AI. The teacher must ensure that the teaching activities for PBL are correct. The students then recall and improve the PBL process by using the experimental folios. The teacher must understand the students' problem-solving procedures. In the meantime, from the teacher's observation, students' consult records, and analytical documents; the data collecting procedure is thus carried out. Then the results can be verified. Finally, the collected data are analyzed and inducted by the quantitative and qualitative research method.

3.2 PBL implementation and course constraints

The primary focus of this research is on the performance evaluation of PBL for students at the Department of Computer Science and Information Engineering, National Formosa University. Consequently, we randomly select the forty-six junior students as the experimental target. They are divided into eleven groups of four or five. A tutor is assigned to each group. This PBL activity is carried out in the weekly lecture hours.

For each lesson plan, the PBL experiment was conducted by the teacher in four continuous weeks.

In the first week, the teacher introduces the execution procedures of the PBL approach to the students and gives them a pre-test regarding the lesson plan. Then the PBL session proceedings start. The teacher assigns the students in turn to serve as a chairperson, a time-keeper, an information correspondent, and an outcome recorder. Under the teacher's supervision, PBL activities are carried out. The files of working procedures contain the problem's discovery and enumeration, analysis and hypothesis, recording learning objectives and issues, action plans, and tasks assignment. The teacher observes the outcome of the PBL session proceedings and writes a teaching diary. After the learning objectives and tasks assignment are done, the group members begin to collect the related data.

In the second and third weeks, each group begins with the learning activities regarding group discussion, collaborative learning, and data analysis. In the fourth week, the conclusion is reported and the teacher interviews the students. Then a post-test for the lesson plan topic and the self-assessment for each group member are made. After the PBL session proceedings are finished, the teacher analyzes the students' learning results and teaching performance based on the pre- and post-test scores, students' learning folios, students' self-assessment records, and so on. Finally, the research report is written down.

Lesson plans (LP) regarding PBL contain the following topics:

- *LP* 1: Self-expression for a robot.
- *LP* 2: Recognition system for fingerprints.
- *LP* 3: The debugging for *C* programs.
- *LP* 4: Machine learning.
- *LP* 5: Intelligence testing for applied networking software and hardware components.
- *LP* 6: Installation of UNIX computer networks.
- *LP* 7: Natural language processing.
- *LP* 8: Automatic updates of anti-virus software and virus prevention agents.
- *LP* 9: Speech recognition system.
- *LP* 10: Computer game—a monster.
- *LP* 11: Assembly of computer hardware.
- *LP* 12: Intelligent JAVA programming language.

The web-based PBL system contains the following menus: PBL concepts, lesson plans, FLASH area, online test, problems bank, discussion area, chat, e-mail, system bulletin board, system manager, the related web-sites, logout, project advisor, and group members.

3.3 Examples of good impulses

An ideal impulse is a real-life problem, which preferably contains some connections to the students' lives and prior knowledge. But the difficulty is to put impulses into action which also cover the entire desired subjects. Examples of good impulses applied in AI 1 and AI 2 are presented below.

Since this PBL course is constrained by the lecture-based one, and since the subject itself is theory-oriented, the themes are not necessarily translated into a practical problem. Therefore, creating suitable impulses are very challenging.

Design Problem: The first impulse given to students is the *Missionaries and Cannibals Problem* [15] in which three missionaries and three cannibals are on one side of a river, with a canoe. They all want to get to the other side of the river. The canoe can only hold one or two people at a time. At no time should there be more cannibals than missionaries on either side of the river, as this would probably result in the missionaries being eaten.

The objective of this impulse is to learn (or recall) graph theory and state space graph. The impulse is good, for it is a real life problem and covers a number of relevant graph concepts, even though most of them should be known from earlier studies. It is also viewed as a good introduction to the PBL system.

Journal Paper: The introduction of the paper [18] "Teaching introductory artificial intelligence using a simple agent framework" was one of the impulses given. The purpose was to faster guide students to acquire more basic concepts regarding graph theory without going through the details of the method presented in the paper. This impulse is, all in all, a good one because it covers precisely the topics needed and acquaints the students with scientific papers.

Predicate Logic: This is fundamentally an extension of propositional logic. It is also sometimes called the predicate calculus. People usually try to limit their use of predicate logic to first-order predicate logic (FOPL). Inference is the process of deducing new facts from the facts that are already known. The capability to deduce new facts to expand our knowledge is extremely important to AI applications. Therefore, the inference rule is the one that lies on the existing FOPL statements to produce new FOPL statements. This impulse stimulates the students to learn the basics of unification and reasoning.

Structures and Strategies for State Space Search: The theory of state space search is our primary tool for answering those questions existing in search algorithms [17]. By representing a problem as a state space graph, we usually adopt graph theory to analyze the structure and complexity of both the problem and the search algorithms that we apply to solve it. This impulse aims at making the hiding and abstract information visible.

Heuristic Search: Heuristics are formalized as rules for selecting those branches in a state space graph that is most likely to obtain an acceptable problem solution. AI problem solvers usually apply heuristics in two basic situations. First, a problem may not have an exact solution due to inherent ambiguities in the problem statement or available data. Second, a problem may have an exact solution, but the computational cost of finding it may be prohibitive. This impulse aims to introduce students in how to defeat the state explosion and find an acceptable solution.

3.4 List of impulses used

All the impulses and the respective subjects to be applied are cursorily listed as follows:

AI 1:

1. Impulse: The Turing test measures the performance of an allegedly intelligent machine against that of a human being, arguably the best and only standard for intelligent behavior. Subject: Imitation game, interrogator, and an intelligent computing machine.
2. Impulse: Missionaries and cannibals problem (Section III-C-1). Subject: State space graph, state space search, problem-solving capability.
3. Impulse: Journal papers (Section III-C-2). Subject: State space graph, state space search, automated reasoning, theorem proving.
4. Impulse: A logic-based financial advisor is an example of the use of predicate logic to represent and reason about the problem domains. Subject: Propositional logic, predicate logic, unification.
5. Impulse: Give the graph representation for the farmer, wolf, goat, and cabbage problem. Let the nodes denote states of the world; e.g., the farmer and the goat are on the west bank and the wolf and cabbage on the east bank. Subject: State space graph, breadth-first search, depth-first search, problem solving capability.
6. Impulse: Consider a three-dimensional tic-tac-toe game and propose a heuristic for playing this game. Subject: Hill-climbing, dynamic programming, heuristic search.
7. Impulse: The knight's tour problem states that a knight can move two squares either horizontally or vertically followed by one square in an orthogonal direction as long as it does not move off the chess board. *Subject*: State space graph, state space search, production rules.
8. Impulse: The 8-puzzle is searched by a production system with loop detection and depth bound 5. Subject: Production system, state space search, data-driven search, goal-driven search.

AI 2:

1. Impulse: Telecommunication systems are large distributed networks of interacting components that require real-time monitoring and management. Agent-based systems have been used for network control and management, transmission and switching, and service. Subject: Knowledge representation, agent-based and distributed problem solving.
2. Impulse: An expert system uses knowledge specific to a certain problem domain in order to provide expert quality performance in that application area. Subject: Interpretation, prediction, diagnosis, design, planning, monitoring, instruction, and control.
3. Impulse: Robot's atomic actions can be found by a planner to accomplish some specific task. *Subject*: Planning, robotics, blocks world.
4. Impulse: A truth maintenance system (TMS) can be used to protect the logical integrity of the conclusions of an inferencing system. It is necessary to recompute support for items in a knowledge base whenever beliefs expressed by the clauses of the knowledge base are revised. Reason maintenance systems address this issue by storing justifications for each inference and then reconsidering support for conclusions in the light of new beliefs. Subject: Chronological backtracking, dependency-directed backtracking, justification-based TMS, assumption-based TMS, logic-based TMS, Bayesian belief network.
5. Impulse: Machine learning is defined as any change in a system that allows it to perform better the second time on repetition of the same task or on another task drawn from the same population. Subject: Neural networks, genetic and evolutionary learning, inductive learning, concept learning, explanation-based learning, supervised learning, unsupervised learning, reinforcement learning.
6. Impulse: A classifier system applies genetic learning to the rules in a production system, which includes production rules (or classifiers), working memory, input sensors (or decoders), and outputs (or effectors). Subject: Genetic learning, conflict resolution, bucket brigade algorithm.
7. Impulse: Resolution is a technique for proving theorems in the propositional or predicate logic and a sound inference rule that, when used to produce a refutation, is also complete. Subject: Binary resolution, resolution refutation, clause form.
8. Impulse: Communicating with natural lan-

guage, whether as text or as speech acts, depends heavily on our knowledge and expectations within the domain of discourse. Understanding language requires not only the transmission of words, but also inferences regarding the speaker's goals, knowledge, and assumptions, as well as the context of the interaction. Subject: Parse tree, transition network parsers, decision tree, story understanding and question answering, an information extraction and summarization system.

4. CHALLENGES

Designing a course by using any pedagogical method requires a huge amount of work. In the PBL method, the greatest challenge might be to develop sufficiently broad lesson plans so that the entire teaching materials are covered [14]. In addition, since the PBL students are required to take the same examinations as those in the traditional course, the order in which these topics are covered is strictly restricted. The easiest way to include these topics in a given order by using the PBL method is to design a multitude of tiny well-defined AI problems working with exactly whatever is required. However, combining all the tiny AI problems together into a larger and interesting lesson plan is also challenging.

One of the key aims of the PBL approach is to practice seeking and filtering a large amount of information, which is obtained by a brain-storming method. Obtaining valuable information becomes a main problem since the students only read ready and available materials. Attempts to tell students to use other sources of information are not very successful. Also, the students seem to find it hard to obtain the valuable materials required for the particular lesson plan from the web sites.

Another challenge is the level and diversity of knowledge owned by third-year students. Some students have a great diversity in the amount of exposure to fundamental concepts of computer science. For example, some students had strong backgrounds regarding discrete mathematics, data structures, algorithm, and computer programming, but some of them did not. Thus the group's prior knowledge results in imbalance. Grouping students based on different levels might resolve the knowledge imbalance.

It can be problematic to give the PBL course to a large number of students. First, university buildings are constructed for simultaneous mass lectures rather than many small-group sessions. Getting enough indoor spaces on campus suitable to PBL small groups might be a problem. Second, a sufficient number of tutors are needed, particularly at the very beginning of a PBL session. This problem can be resolved especially when the students have already studied the PBL methodology, by having one teacher carefully observe proceedings in several groups for a period of time.

5. LEARNING RESULTS AND STUDENT FEEDBACK

Feedback on the AI course is achieved by asking the students to fill in a questionnaire on the Internet anonymously [19–20]. Each student may complete the questionnaire once; personal data are separated from the questionnaire response. Some of the questions in the questionnaire are fixed, while others may be given freely by the course teachers. Three questions were common to both the PBL course and the traditional lecture-tutorial course:

- Q1-"What overall grade would you give to this course?",
- Q2-"How much work did you need to put in for the credit units earned?"
- Q3-"How well did the exam measure the issues covered in this course?"
- The result of the response to the query "What overall grade would you give to this course?" on the scale 1 ="poor" to 5 = "excellent". The mean and standard deviation are 4.08 and 0.57 for the PBL approach and 3.76 and 0.81 for the traditional course students, respectively.
- The result of the response to the query "How much work did you need to put in for the credit units earned?" on the scale 1 ="too much work" to 5 = "too little work". The mean and standard deviation are 2.72 and 0.59 for the PBL approach and 2.68 and 0.49 for the traditional course students, respectively.
- The result of the response to the query "How well did the exam measure the issues covered in this course?" on the scale 1 ="miserably" to 5 = "very well". The mean and standard deviation are 3.98 and 0.61 for the PBL approach and 3.67 and 0.83 for the traditional course students, respectively.

According to the above results, if the mean 3.80 is set to be a success criterion, then Q1 and Q3 have reached the success criterion; but Q2 has not reached the success criterion yet.

5.1 Satisfaction level evaluation

The results in satisfaction level from the questionnaire are presented below. Also, the percentage indicates the degree of affirmation by the participants.

1. The PBL sessions have improved my understanding of the lectures provided within this module. (89%)
2. The PBL sessions have helped my understanding of the theoretical network design process. (82%)
3. The PBL sessions have improved my understanding of the practical aspects of AI algorithm design. (71%)
4. Having participated in the PBL sessions, my confidence and ability to undertake a real AI algorithm design has been enhanced. (73%)

Table 1. Pre- and post-test scores for Question 1

	# Students	Lowest	Highest	Average	Standard Deviation
Pre-test	46	17	78	50.43	13.25
Post-test	46	32	92	56.71	14.22
N	46				

Table 2. t-test summary of scores

	# Students	Average	Standard Deviation	t Values	Significance
Pre-test	46	50.43	13.25	−2.771	0.22*
Post-test	46	56.71	14.22		

*$p < 0.05$

Table 3. Pre- and post-test scores for Question 2

	# Students	Lowest	Highest	Average	Standard Deviation
Pre-test	46	20	82	52.10	11.15
Post-test	46	28	93	66.21	14.21
	46				

Table 4. t-test summary for the pre- and post-tests

	# Students	Average	Standard Deviation	t Values	Significance
Pre-test	46	52.10	11.15	−6.212	0.007**
Post-test	46	66.21	14.21		

**$p < 0.01$

5. The PBL sessions were realistic and reflected typical real practical situations. (68%)
6. The PBL sessions have helped my ability to work in groups. (80%)
7. The PBL sessions were well organized and effective. (79%)
8. The PBL sessions should be kept as part of this module. (87%)
9. How motivating do you feel the PBL method was? (Very motivating, 81%)
10. How much harder did you work than usual? (Much harder, 78%)
11. How well did you feel learned the course matter? (Very well, 89%)
12. How was your learning experience? (Fun, 88%)

According to the above results, if the satisfaction level 75% is set to be a success criterion, then those items except (3), (4), (5) have reached the success criterion.

5.2 Data analysis for pre- and post-tests

How do you deal with the problem of AI instruction system infected by a virus?

1. Pre- and post-tests scores

Based on the pre- and post-tests for the PBL approach, the related scores are shown in Table 1. The number of participants is 46. For the pre-test, the highest score is 78, the lowest score 17, and the average 50.43. For the post-test, the highest score is 92 and the lowest score 32, the average 56.71.

2. t-test for pre- and post-tests

Based on the research purposes, the related scores are analyzed accordingly. The pre- and post-tests' scores for the PBL approach are t-tested as shown in Table 2. As the t-tested results, the standard deviation of the scores is up to the level of significant difference. This indicates that the students' academic achievements have been significantly improved after the PBL teaching activities are conducted. In other words, the PBL activities can remarkably enhance the teaching performance.

Question 2: What do you want to do if students are unfamiliar with JAVA programming language?

3. Pre- and post-test scores

Based on the pre- and post-tests for the PBL approach, the related scores are shown in Table 3. The number of participants is 46. For the pre-test, the highest score is 82, the lowest score 20, and the average 52.10. For the post-test, the highest score is 93 and the lowest score 28, the average 66.21.

4. t-test for pre- and post-tests

Based on the research purposes, the related scores are analyzed accordingly. The pre- and post-test scores for PBL are t-tested as shown in Table 4. As the t-tested results, the standard deviation of the scores is also up to the difference of significance. Similarly, this indicates that the students' academic achievements have been significantly improved after the PBL teaching activities are conducted. In other words, the PBL activities can remarkably enhance the teaching performance.

5.3 Discussion

1. Students' learning performance has been improved since the difference between the pre-test and the post-test for the PBL course has reached the level of significance.
2. Students participating in the PBL activity have increased their domain knowledge to some extent since they understood how to collect references, how to analyze the data, and how to share their domain knowledge with one another during group discussion.
3. The students have also increased their self-learning capability since they learned how to collect multi-data by using textbooks, references, magazines, and computer internet resources.
4. The students have increased their problem-solving capability since they completely understood the problem-solving methods and procedures; also since they knew how to solve problems using computer internet resources.

6. CONCLUSIONS

The PBL approach has been successfully used in National Formosa University since 2003 to teach Artificial Intelligence to junior students. Although the PBL approach has been used for several years, this study is the first systematic attempt to compare the PBL approach with the traditional one in National Formosa University.

The above results of the comparison, made by using a questionnaire and the average examination score obtained by the students in the PBL and traditional courses, seem to adjust the scales in favor of the PBL approach. Student learning interests and participation can obviously be increased and the difference between pre-tests and post-tests is up to the level of significance.

For general learning performance, this study indicates that the students have enhanced their capabilities regarding knowledge integration, self-learning, data-collecting, and collaborative learning. For the applications of domain knowledge, students have learned how to collect multi-data and then to perform data analysis, induction, and presentation. For self-learning, students clearly understand how to actively participate in PBL activities and how to learn the importance of brainstorming. For their problem-solving capability, they also learn how to analyze problem-related data, to construct the knowledge framework, and how to use problem-solving methods.

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