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AN INDUCTIVE, INTERACTIVE AND ADAPTIVE HYBRID PROBLEM-BASED LEARNING METHODOLOGY: APPLICATION TO STATISTICS

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Abstract

We have developed an innovative hybrid problem-based learning (PBL) methodology. The methodology has the following distinctive features: i) Each complex question was decomposed into a set of coherent finer subquestions by following the carefully designed criteria to maintain a delicate balance between guiding the students and inspiring them to think independently. This learning methodology enabled the students to solve the complex questions progressively in an inductive context. ii) Facilitated by the utilization of our web-based learning systems, the teacher was able to interact with the students intensively and could allocate more teaching time to provide tailor-made feedback for individual student. The students were actively engaged in the learning activities, stimulated by the intensive interaction. iii) The answers submitted by the students could be automatically consolidated in the report of the Moodle system in real-time. The teacher could adjust the teaching schedule and focus of the class to adapt to the learning progress of the students by analysing the automatically generated report and log files of the web-based learning system. As a result, the attendance rate of the students increased from about 50% to more than 90%, and the students' learning motivation have been significantly enhanced.

Keywords: Problem-based learning, Statistics.

1. Introduction

The hybrid problem-based learning (PBL) approach (also called blended instruction or b-learning) combines the conventional face-to-face teaching method and the computer-aided on-line techniques [1-12]. The regular teaching part of the hybrid PBL approach is complemented by on-line computer-aided practical part. Compared to the traditional face-to-face teaching method, the advantages of

hybrid PBL approach can be summarized as followings: (i) The computer-aided practical class session of the hybrid PBL approach creates a flexible self-learning environment for the students. The students' understanding of the theoretical concepts that they learned in the face-to-face teaching part can be strengthened and consolidated through the computer-aided practice and the internalization of the problem-solving procedures can be expedited without incurring extra tutoring cost. (ii) Immediate feedback can be generated automatically by the web-based learning system, which will facilitate the students to determine the points at which they are stuck and stimulate them to overcome these barriers without leading to frustration or boredom.

Due to the abovementioned advantages, hybrid teaching methodology has been intensively researched and experimented [1-12]. The research work related to b-learning and the incorporation of information and communication technology (ICT) into traditional teaching mode can be found in the literature [1-13]. In addition, some representative studies which compared b-learning and traditional face-to-face teaching can be referred to the following references [14-19].

Despite some contradiction in the literature, it is generally believed that the hybrid PBL learning methodology can enhance the interests and motivations of the students compared to the conventional face-to-face teaching approach. However, most of the studies show that the success rate will not be improved much by adopting the hybrid approach [14-19]. How to further develop innovative hybrid PBL approaches that utilize the modern information and communication technology to improve the learning outcome and success rate remains an interesting research topic in the field of science and engineering education.

"In his policy speech in 2000, the then Chief Executive of the Hong Kong Special Administrative Region set in motion a series of initiatives that have transformed the post-secondary sector in Hong Kong. The policy objectives included enabling 60% of senior secondary school leavers of the 17-20 age group to receive full-time post-secondary education by 2010, and supporting learning throughout the working life until 60 years of age. It was clear that there was room for the self-financing sub-degree (SFSD) sector to take the lead in responding to society's demand for lifelong learning opportunities. The Hong Kong Government would provide incentives and assistance for providers through land grants, start-up loans and accreditation grants to institutions and financial assistance for needy students."

In response to the pledge in the above Chief Executive's Policy Address 2000 to expand tertiary education under the initiative of the Education and Manpower Bureau [20], Hong Kong Institute of Technology (HKIT) was set up as a non-profit making tertiary institute. HKIT aspires to become a high quality educational institution with a focus on international education. It encourages the academic staff to design and develop innovative teaching methods, and is in the constant quest for improvement of teaching facility and environment. It adopts a flexible policy allowing students to transfer between full-time (FT) and part-time (PT) modes according to their employment status. The policy has attracted a number of PT students, who registered in the evening classes and attended classes after their day's work. However, we observed that the PT students easily get worn out after their work and thereby they usually will not have much time to consolidate their knowledge after a full day of working. In addition, they enrolled more than one

course in one semester in order to expedite the total study progress. For this group of students, we develop a tailor-made teaching methodology to motivate them and maximize the achievement of the learning outcomes in the class.

Statistics is one of the most fundamental and broad subjects underpinning many of the other disciplines of science and engineering such as economics, physics and biology etc. It is used in many areas and professions in society. Inferred from the students' feedback and the low success rate in the past, we observe that it is one of the most challenging subjects which many students are not confident to cope with.

Considering the students' background, practical situations and the limitations of available hybrid PBL approach, we develop an inductive, interactive and adaptive methodology to enhance the students' learning motivation in line with the institution's mission of providing high quality education. The *distinctive* features of our approach are listed below:

- Our approach is inductive in nature. By subdividing the complex problem into a series of coherent concepts or procedures, the students can be guided and self-directed toward solving the subsequent sub-questions in cognitive domain which are new to them, based on their experiences and subjective perception in the previous steps.
- Instead of automatically providing the hints to the students by the web-based system, we stress the importance of interaction between the students and the teacher. It is the teacher instead of the web-based system that provides the response-dependent hints to stimulate the students to find useful information to solve the problems. The web-based learning techniques are utilized to create a virtual learning environment to facilitate the interaction.
- The teaching is conducted in an adaptive manner and the teacher dynamically adjusts the teaching focus based on the feedback generated from the web-based learning system in real-time. In addition, the weak area of the students can be easily identified and thus the teacher can accordingly adjust the level of difficulties and focus of the next class to adapt to the students' progress.

The main objective of our designed teaching method is to maximize the learning outcome of the students in class. This is particularly important for PT students in our case. Our methodology has been applied to statistics, however it can easily be extended to any disciplines to facilitate the students to acquire knowledge and master the problem-solving skills.

2. Methodology

Our methodology was developed and applied in Statistics course taught at Hong Kong Institute of Technology in summer term of 2010. The 36-hour course lasted for 12 weeks, and was divided into 24 hours of regular lectures and 12 hours of tutorial activities. The objective of the course was to provide students with opportunities to be exposed to an extensive range of statistical tools and techniques, and prepare the students for lifelong learning by developing statistical literacy. The major topics of the course include Descriptive statistics and probability, Continuous probability distributions, Sampling distributions, Hypothesis testing, Chi-squared tests, Anova, Simple linear regression and correlation, and Decision theory, etc. Both the theoretical concepts and the practical problem-solving skills in the context of statistic research and methods are equally emphasized.

The 24 regular lectures were mainly devoted to helping students to understand the fundamental concepts and theories, while the 12 tutorial hours provided real life practices to facilitate the internalization of the problem-solving [21].

2.1. Classroom equipments and software tools

The statistics class for PT associate degree (AD) at postsecondary level and degree students was arranged on every Thursday evening, and was conducted in one of the computer laboratories of HKIT. There are over 50 desktop computers in the laboratory and all the computers are equipped with a wide range of software resources. All the computers are constantly upgraded and maintained at high academic standards by the IT department to enable the students to acquire the necessary computer skills.

There are many available software companies in Hong Kong which provide online teaching and self-learning system solutions for the education sector. However, it is an important concern for all the self-financing postsecondary institutions in the sub-degree sector of Hong Kong to find the optimized solutions in achieving both quality education and cost-effectiveness. The free systems Moodle (Modular Object Oriented Dynamic Learning Environment) used by HKIT serves a good practice in this regard. Moodle is one of the many virtual learning platforms based on Course Management Systems (CMS) [21-22], which provides a user-friendly web interface for the lecturers to prepare and distribute course materials and information, and create the on-line activities including assignments and on-line tests etc. It has many excellent built-in modules such as the forum module, which provides a real-time synchronous discussion environment for students to exchange ideas and for the lecturer to manage and promote learning. The most attractive feature should be its evolving nature of open-source which allows all the enthusiastic users of the learning community worldwide to contribute to its development and improvement.

Moodle was installed and used as our on-line learning system for the past several years. Almost all the courses offered by HKIT use Moodle, and it is well supported by the IT department of HKIT. The time needed to train the students to use the system is minimum.

Considering all these advantages of Moodle, we implemented our methodology on our Moodle teaching platform and install some built-in modules to facilitate our implementation. The most important built-in module which we installed and modified for performing our methodology is "Quiz" module. It is worth noted that an additional function of the module is to record the class attendance of the students. We have also added some functions such as typing mathematical symbols and generating random numbers etc. in the modules to assist our teaching.

2.2. Features of the Proposed Teaching Methodology

2.2.1. Inductive

Unlike most of the teaching arrangement of conducting the regular lectures and the practical classes on different days, we combined the two sessions in one. Each class lasted three hours, including two hours' regular teaching followed by one hour's tutorial session.

According to available research studies regarding the effect of immediate and delayed feedback on the learning outcome, it is generally believed that immediate feedback will lead to an enhanced motivation/satisfaction and better training behaviour [23]. Thereby the arrangement of combining regular teaching session and the tutorial session in the same class possesses the advantage over the traditional teaching arrangement where the lecture and tutorial sessions are carried out on different days.

In the two hours' regular teaching section (Section 1), the teacher introduced and explained the basic and important concepts and theory. It was delivered in the format of powerpoint presentation. In this session, each concept was immediately followed by a short or multiple-choice (MC) question to enhance the students' understanding and comprehension. The short or MC question could also be used to identify those concepts that puzzle or confuse the students. These short and MC questions were selected from the question pool created by the teacher at the beginning of the semester. Screenshot of one typical MC question on the Moodle system is shown in Fig. 1. After several repetitive practices of each key concept, most of the students were able to apply the theoretical concepts to a variety of practical situations.

The second part was one hour's tutorial section (Section 2). The students worked on some complex and practical statistical questions on the Moodle system. Each question was finely divided into many smaller sub-questions based on the principles of learning and logical thinking:

- The sub-questions must be arranged in a logic sequence so that the student can correlate all the sub-questions and develop a coherent picture of the complex question.
- There exists an optimized level of details for decomposition of the complex question into finer sub-questions.
- If the level of details exceeds the optimized level, i.e., if the question is overly refined and excessively subdivided, the students will be lost in the details and unable to follow the logic behind the decomposition and the big picture. The question refining criteria needs to be carefully designed to ensure that the students will not be deprived of their independent thinking and reasoning ability.

The inductive teaching approach must allow the students to solve the question progressively, and most importantly, maintain a delicate balance between guiding the student and inspiring them to think independently.

It is worth noted that the data pool must be updated after each class. The teacher needs to design and import new questions into the data pool of the web-based learning system to adapt to the students' progress.

2.2.2. Interactive

The available hybrid PBL methodology consists of face-to-face theoretical class session and on-line computer-aided practical class session. Unfortunately, the two sessions are not (or only loosely) integrated in an organic whole. The practical class session is arranged on different day of the regular lecture with very little (or without) tutor assistance. Although such arrangement will reduce the tutoring cost, the students only interact with the virtual learning environment instead of the teacher. In our approach, the students need to interact intensively with the teacher for both the regular teaching part and the on-line tutorial part. And these two parts are combined in one class session. The interactive feature of our approach can be

reflected in the following two sections of the class (the regular teaching and the tutorial part).

Section 1: As described in (2.2.1), the teacher complements the traditional lecture format with the on-line short and MC questions. In a traditional face-to-face teaching class, the teacher needs to frequently stop and ask questions during the introduction and elaboration of new concepts, which is the only interactive means between the teacher and the students in most cases. However, this will largely depend on the individual teaching style and the nature of the disciplines. In contrast with the traditional face-to-face teaching mode, the interactive portion of our approach can be greatly increased due to the organic integration of the teaching activities and the utilization of on-line learning system. Such intensive interaction can make the students highly involved in the learning process, and stimulate them to think actively instead of losing focus and daydreaming.

Section 2: The learning system can compare the answers of the students with the predetermined standard answers in the database and will give a full mark if the students' answers lie within a certain range of tolerance of the correct solution. The students can have multiple attempts at the same question until he/she gives the correct answer or abandons further attempts. The function of automatically providing hints to the students by the system is intentionally suppressed. The teacher will indentify the steps or concepts which pose difficulties for those students to continue by checking the real-time on-line report of the system. Then the teacher will elaborate on the particular steps in which these difficulties and misunderstandings occur to help the students continue. The teacher will interact with individual students to help them figure out the cause of difficulties. This interactive process takes into account of the diversity of the students and enables the students to receive immediate and personalized guidance and supervision.

It should be noted that the order of the options of the MC questions is randomized for different students so that it is meaningless to simply copy other's answers. In addition, it is worthy of note that the log file generated by the on-line system can also be used to check the attendance of the students.

Case Study

In one class, the concepts "population mean" and "sample mean" were introduced and explained to the students. If we have a sample from a population involving an unknown population mean, we can use the sample mean to estimate the corresponding unknown population mean. The sample mean is a random variable, since its value depends on what particular random sample we draw each time. The students seemed to understand this concept and no questions were raised. But how to check whether the students indeed understand the actual meaning of the concept? In our learning approach, one MC question was designed for all the students to answer. The screenshot of the question is shown in Fig. 1.

Once the students submitted their answers on-line, a report can be automatically generated and the teacher could check the correctness of their answers in the report. A screenshot of such report is shown in Fig. 2. The report also includes the information whether some students failed to submit their answers, based on which the teacher can identify the likely sources of their difficulties (one was actually half-sleeping). Surprisingly, many students chose a and b (the correct answers should be a and c). They apparently did not, or at least

not comprehensively, understand the underlying meaning associated with this concept. By working on the MC question, the students realized that their understanding of the concept is still superficial and vague. Thereby they would be stimulated to actively engage in the learning activities.

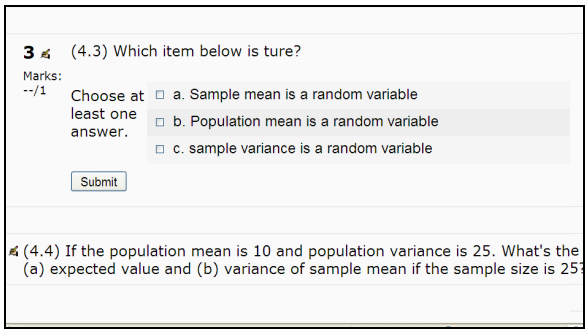


Fig. 1. Screenshot of one Multiple Choice Question on "Sample Mean" in the Evening Class of July 8, 2010.

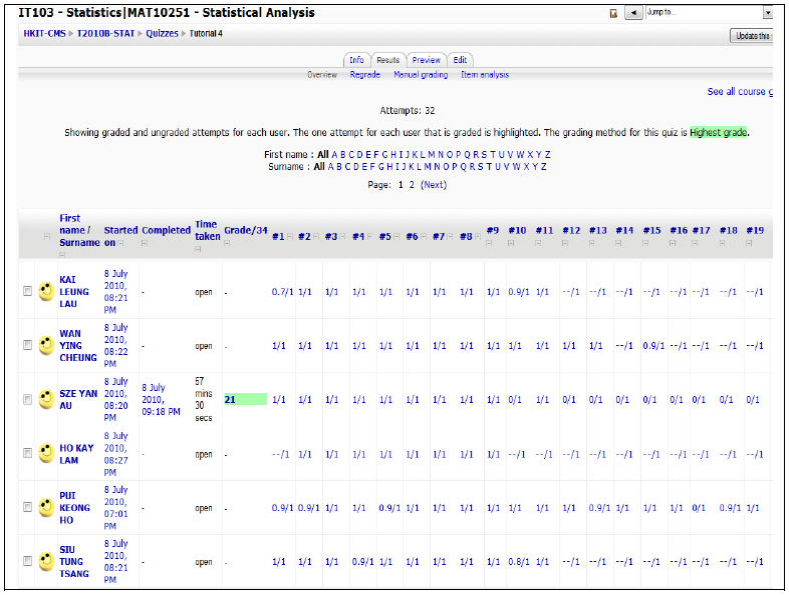


Fig. 2. Screenshot of the Automatic Report Generated by Moodle.

This could not be achieved in the traditional face-to-face teaching class, because it was meaningless for the teacher to ask all the students to answer the question one by one. And it would be impractical for the teacher to do so with a class size of more than 20 students since it takes too much time. Even the teacher walked around to check the answers written down by the students on their papers/notebooks, he or she could only have a rough estimate of the percentage of the students who give the right and wrong answers. The whole process would take much longer time compared to our approach.

2.2.3. Adaptive

Based on the intensive interaction with the students, the teacher could easily obtain the information regarding the students' learning progress and then take appropriate measures to adapt to the students' progress. The on-line report could be readily extracted from the web-based learning system to facilitate this adaptive process. For example, in the above case in (2.2.2) the teacher might give one example to further help students differentiate the differences between "population mean" and "sample mean", and get the half-sleeping one back to real life by asking him to give one example. The teacher might also need to include one or two questions on "sample mean" in the question pool of the next class to consolidate and deepen their understanding. In this way, the students received personalized tutoring and their motivation of study will be increased.

3. Results and Discussion

We have compared the students' learning behavior and the level of engagement in the classroom before and after adopting our methodology, which is summarized in Table 1.

From Table 1 it can be seen that the web learning system helped promote a dynamic and interactive class atmosphere. The new teaching approach indeed fostered the students' learning process and greatly boosted their learning enthusiasm. It is important to know how students feel about studying statistics by our new approach. To study the actual impact of adopting our new teaching methodology in a more comprehensive way, we designed a questionnaire to obtain the information about learning behavior and satisfaction of the students.

Table 1. Comparison of Students' Learning-Related Behaviour and Motivation before and after Adopting our Methodology.

	Before adopting the methodology	After adopting the methodology
1.	50%-60% attendance rate	90%-100% attendance rate
2.	Most of the students are passive listener and seldom ask questions.	Most of the students ask questions and get actively involved.
3.	Some students arrive several minutes later than the class starting time.	Most of the students arrive on time.
4.	Some students leave the classroom before the class is over.	Almost all the students stay until the last minute of the class.
5.	Most of the students leave once class is over.	Some students stay and continue to discuss with others and with the teacher after the class.

3.1. Design of the questionnaire

The questionnaire was designed to help the teacher to know and understand the needs and requirements by the students, and to adjust the style and method of teaching accordingly to better meet the student's needs. The ultimate goal was to improve their final overall grades of this course. The motivation of the questionnaire has been explained to the students in class.

The questionnaire consisted of ten close-ended questions and one open-ended question. The first three questions in the questionnaire were related to their normal working load and employment status, which will not be discussed in this paper. The last open-question was designed to obtain the students' suggestions to further improve our teaching approach. In total, there were 37 students who submitted the questionnaire anonymously.

3.2. Analysis of the questionnaire answers by the students

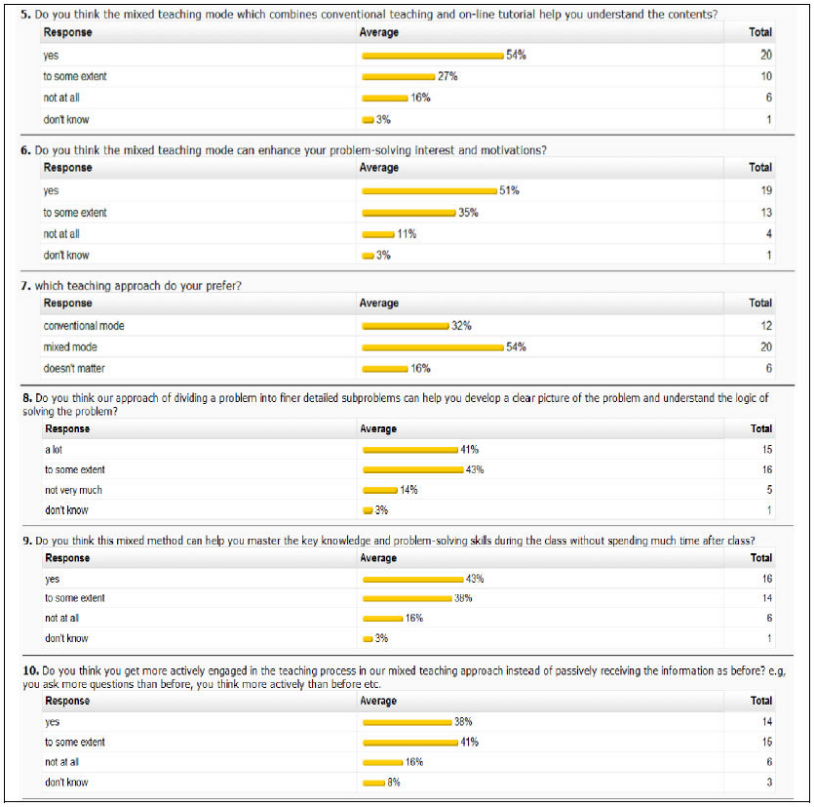
Figure 3 shows the students' answers of the six questions in the questionnaire. Q5-Q7 were designed to check whether the students were satisfied with our new teaching approach. 81% of the students thought the mixed teaching method helped them to understand the contents (Q5). Furthermore, 86% of the students believed the method could enhance their learning interest and motivations (Q6). As a result, 54% of the students preferred mixed teaching mode. We also noticed that there was a significant proportion (32%) of the students who preferred the conventional mode (Q7). Further study will be made to investigate the factors that may affect the preference of the students.

Q8 was designed to obtain the opinion of the students on our inductive method of subdividing the complex questions into detailed steps in a logical sequence. Most of the students believed that our approach of dividing a complex question into finer detailed sub-questions could help them develop a clear picture of the question and understand the logic of solving the question in an inductive context. A total of 84% of the students chose 'yes' or 'to some extent'.

81% of the students thought this mixed method could help them master the key knowledge and problem-solving skills without spending much time after class (Q9). This result was in line with our objective of maximizing the learning potential of the students in class, which was particularly important for the part-time students since they did not have much time for self-learning after class. In addition, 79% of the students were actively engaged in the teaching process in our mixed teaching approach instead of passively receiving the information as in the traditional teaching environment (Q10). The intensified involvement of the students was the major reason of the increased satisfaction level and learning outcome as reflected by the questionnaire answers and continuous assessments.

It should be noted that the students could select multiple answers for the questions in the questionnaire. One student submitted two answers for Q7 and Q10, leading to a sum of 38 for those two questions. Some adjustments (e.g., set the maximum number of choices depending on the nature of the questions) will be made to further improve the questionnaire design.

The last open-question was designed to obtain the students' comments of our teaching approach. It is optional for the students to answer this question. 9 out of the 37 students submitted their comments. 4 out of the 9 students who submitted their suggestions thought that the new teaching method was a good attempt and the learning process was pleasant and wonderful. The other 5 suggestions were about the medium of instruction used in the teaching. The 5 students preferred Chinese instead of English as the medium of instruction in class teaching. Since these suggestions are not directly related to our teaching approach, we will not discuss Q11 in detail.



5. Do you think the mixed teaching mode which combines conventional teaching and on-line tutorial help you understand the contents?

Response	Average	Total
yes	54%	20
to some extent	27%	10
not at all	16%	6
don't know	3%	1

6. Do you think the mixed teaching mode can enhance your problem-solving interest and motivations?

Response	Average	Total
yes	51%	19
to some extent	35%	13
not at all	11%	4
don't know	3%	1

7. which teaching approach do your prefer?

Response	Average	Total
conventional mode	32%	12
mixed mode	54%	20
doesn't matter	16%	6

8. Do you think our approach of dividing a problem into finer detailed subproblems can help you develop a clear picture of the problem and understand the logic of solving the problem?

Response	Average	Total
a lot	41%	15
to some extent	43%	16
not very much	14%	5
don't know	3%	1

9. Do you think this mixed method can help you master the key knowledge and problem-solving skills during the class without spending much time after class?

Response	Average	Total
yes	43%	16
to some extent	38%	14
not at all	16%	6
don't know	3%	1

10. Do you think you get more actively engaged in the teaching process in our mixed teaching approach instead of passively receiving the information as before? e.g, you ask more questions than before, you think more actively than before etc.

Response	Average	Total
yes	38%	14
to some extent	41%	16
not at all	16%	6
don't know	8%	3

Fig. 3. Screenshot of the Automatic Analysis of the Student Feedback.

In all, the feedback from the students are encouraging and the increasing satisfaction of the students are the best incentive for us to further improve and design innovative learning methodology, especially for teaching the difficult subjects such as statistics.

4. Conclusions

We have designed and implemented an innovative hybrid teaching methodology. Such methodology is general and can be applied in any subjects which center on the development of problem-solving skills of the students. In particular, we apply the approach in the Statistics class consisting of a group of students who have full-time job and thus do not have enough time for self-learning after classes.

The decomposition of the complex questions is designed in an inductive manner to train the students to approach the solution through an optimized procedure subconsciously. The close interaction between the teacher and the students play a pivotal role to ensure the successful delivery of knowledge to the students. With the real-time automatic feedback generated by the web-based learning system, the teacher can easily obtain information about the learning process of the students so as to take adaptive measures to cope with the various

needs of the students. This information allows teachers to focus on the concepts and steps in which students have more difficulties.

Some possible factors which may hinder the adoption of our approach by others are summarized as follows:

a) The teacher will need more time to create, update, and carefully select the questions in the question pool than the traditional teaching approach, where the teacher can simply use paper-based questions and hand them out to the students in class.

b) It needs institutional full support for adoption of such teaching methodology. The class can only be conducted in the classroom equipped with computers and network. This may pose difficulties for some institutes with very limited teaching resources and tight teaching budget.

The students' performance and learning attitude were significantly improved by adopting our innovative hybrid PBL learning approach, as reflected in the students' feedback. We believe that our teaching approach will provide some useful guidelines for our peer tertiary institutes to design innovative teaching methodology and outline a promising research direction in the field of student-centric hybrid learning.

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