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Implementing Problem Based Learning Strategies to Optimize Science Instruction for Learner Engagement

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ABSTRACT

This paper presents the development of the C2HADAM multimedia courseware prototype, employing a Problem-Based Learning (PBL) approach for teaching Science to Form Two students in selected Malaysian secondary schools. Despite the recognized benefits of Problem-Based Learning (PBL) in enhancing student engagement and understanding in the Science course, there is a lack of multimedia courseware that effectively integrates PBL with constructivist, collaborative, inquiry-based, and exploratory learning principles for Form Two students in Malaysian secondary schools. The paper begins by outlining the theoretical and conceptual frameworks that inform the architecture of C^{2}HADAM, emphasizing the application of renowned learning theories such as constructivism and collaborative learning, as well as PBL itself. Additionally, C^{2}HADAM incorporates principles of inquiry-based learning, simulations, exploratory learning, and a student-centred approach. Further, the paper delineates the life cycle of the courseware's development, which includes phases of analysis, design, development, implementation, and evaluation. In conclusion, the paper presents testing results from assessing the courseware's effectiveness.

1. Introduction

This paper examines the creation of the multimedia courseware package, C^{2}HADAM, which is designed to support the instruction of the Science topic of Nutrition. The development of this resource is grounded in the Problem Based Learning (PBL) methodology. Recognized for its growing popularity, PBL represents a transformative approach to the educational process. Additionally, the rapid expansion of Internet and multimedia technologies has served as a driving force behind the evolution of the educational landscape in our country. The integration of Information and Communication Technologies (ICT) in learning provides students with diverse educational settings and the opportunity for authentic, hands-on experiences, as noted by Zumbach *et al*., [1]. This paper begins with the discussion of several learning theories adopted in the development of the C^{2}HADAM multimedia package. Among the learning theories are PBL, Constructivism, and Collaborative

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Approaches. The second section of the paper presents the development of C²HADAM module and the third section discusses the findings from a case study conducted with a number of selected schools.

Constructivist learning theory, which emphasizes exploratory and problem-solving activities, has inspired a variety of pedagogical techniques. These include situational learning, and cooperative learning [2]. However, according to Savery and Duffy [3], as well as Jonassen [4], PBL stands out as the most authentic application of constructivist principles. Consequently, PBL has been selected as the preferred instructional method for the development of this multimedia courseware, particularly due to its effectiveness in science education [5].

PBL is defined by Barrows and Tamblyn [6] as an educational approach where learning happened by solving real and ill-structured problems. From the previous studies [7,8], they elaborate that PBL involves engaging learners with a series of problems that require critical and creative thinking to solve. These problems should reflect real-world scenarios, which is a crucial aspect of PBL. The design of these situations is intentional, aiming to achieve specific learning outcomes and develop necessary skills. Presenting learners with real problems at the outset of their education is a foundational step in PBL as stated by several authors in their previous studies [9-11]. This early exposure encourages learners to apply their problem-solving abilities, logical reasoning and knowledge. Furthermore, these problem scenarios act as an introduction to the broader subject matter, stimulating the learners' interest and curiosity in the topics to follow. The role of educators has changed from mere knowledge transmitters to learning facilitators and educational innovators [12].

Remedios *et al*., [13] state that collaborative learning does not only allow the learners to participate actively in a discussion, but also promote a sense of responsibility for their own learning. In fact, learners are trained to think critically. According to Wiersema [14] and Corderoy [15] collaborative learning is a philosophy in education, requiring the learners to cooperate, work, learn and advance together. Yahoo Group and Google on the Internet are effective tools for collaborative learning, information sharing, communication and soft skills development in learning Science as stated by several authors in [16-18]. Competences, which include a blend of academic knowledge, technical expertise, self-management skills, and the ability to work effectively in teams, are ideally suited to the PBL methodology [19-21]. The objective of this research is to study the effect of PBL technique in learning Science.

This paper begins with the discussion of several learning theories adopted in the development of the C²HADAM multimedia package. Among the learning theories are PBL, Constructivism and Collaborative Approaches. The second section of the paper presents the development of C²HADAM module and the third section discusses the findings from a case study conducted with a number of selected schools.

2. The C²HADAM Multimedia Package Development Model

The theoretical frameworks of constructivism and collaborative learning underpin the design of C²HADAM, ensuring an interactive and student-centred learning experience. Constructivism emphasizes active knowledge construction, which is reflected in C²HADAM's problem-based simulations and real-world scenarios. For example, when students explore human digestion, they engage in interactive multimedia activities where they diagnose digestive disorders, applying prior knowledge to new contexts. Collaborative learning is embedded through peer discussions and group-based problem-solving tasks, fostering knowledge co-construction [22]. Features such as interactive quizzes, discussion forums, and guided reflections encourage deeper engagement, demonstrating how these theories inform C²HADAM's pedagogical approach.

The development of the C²HADAM multimedia courseware is structured around a five-phase process, referred to as the Life Cycle Model of C2HADAM (KH C²HADAM). This comprehensive model integrates the previously mentioned learning theories and encompasses several key development facets: (i) analyzing the methodologies of PBL for teaching and learning; (ii) crafting learning outcomes aligned with the Instructional Design (ID) model and the C²HADAM courseware; (iii) devising a detailed teaching plan; and (iv) executing assessments and (v) refining the system in accordance with the KH C²HADAM. The most important part in implementing PBL is creating a problem scenario. It must be designed to align with learning outcomes by presenting real-life problems that encourage inquiry and application. For example, in studying the human digestion system, students investigate a case of digestive disorders and linking them to enzyme functions and nutrient absorption. This approach fosters critical thinking, problem-solving, and deeper scientific understanding.

The KH C²HADAM, which employs the hybrid PBL approach for the teaching of science subject for From Two students (on the topic Nutrition), also encompasses five standard phases of common life cycle development, as shown in Figure 1 whereas Figure 2 shows Modules and Submodules of C2HADAM Courseware. The KH C²HADAM also takes into consideration some entities like the learning concept of the hybrid PBL, the lesson plan for the topic Nutrition, the elements for the development of C²HADAM courseware, the elements for the development of C²HADAM Sheet and the constructs involved in the evaluation of the C²HADAM courseware. This model, named as KH C²HADAM, consists of three layers (L1-L3), which are:

i. L1: This is the outer most layer which includes the appropriate environments for PBL approach: The Methodology of PBL Teaching and Learning, The Learning Outcomes of PBL, The PBL Data or Details, and The Developer and User of PBL.
ii. L2: This second layer is the inner layer that covers the five standard development phases. These five processes are performed iteratively until zero rectification, otherwise, up to the expectation of the consumers. This is the main layer for the Life Cycle of Development process.
iii. L3: This is the intra-internal layer that comprises of entities related to human-centred computerisation. The entities include: lesson details, PBL features and learning activities, ID model construction, courseware modules development, teaching content inventory, C²HADAM courseware and C²HADAM Sheet module development, the IMM-PBL Scenario Development Model construction, quasi-experiment evaluation, human factor modification, and application evaluation based on the five constructs: effectiveness, learnability, userfriendliness, flexibility and learners' attitude towards the use of C²HADAM multimedia package

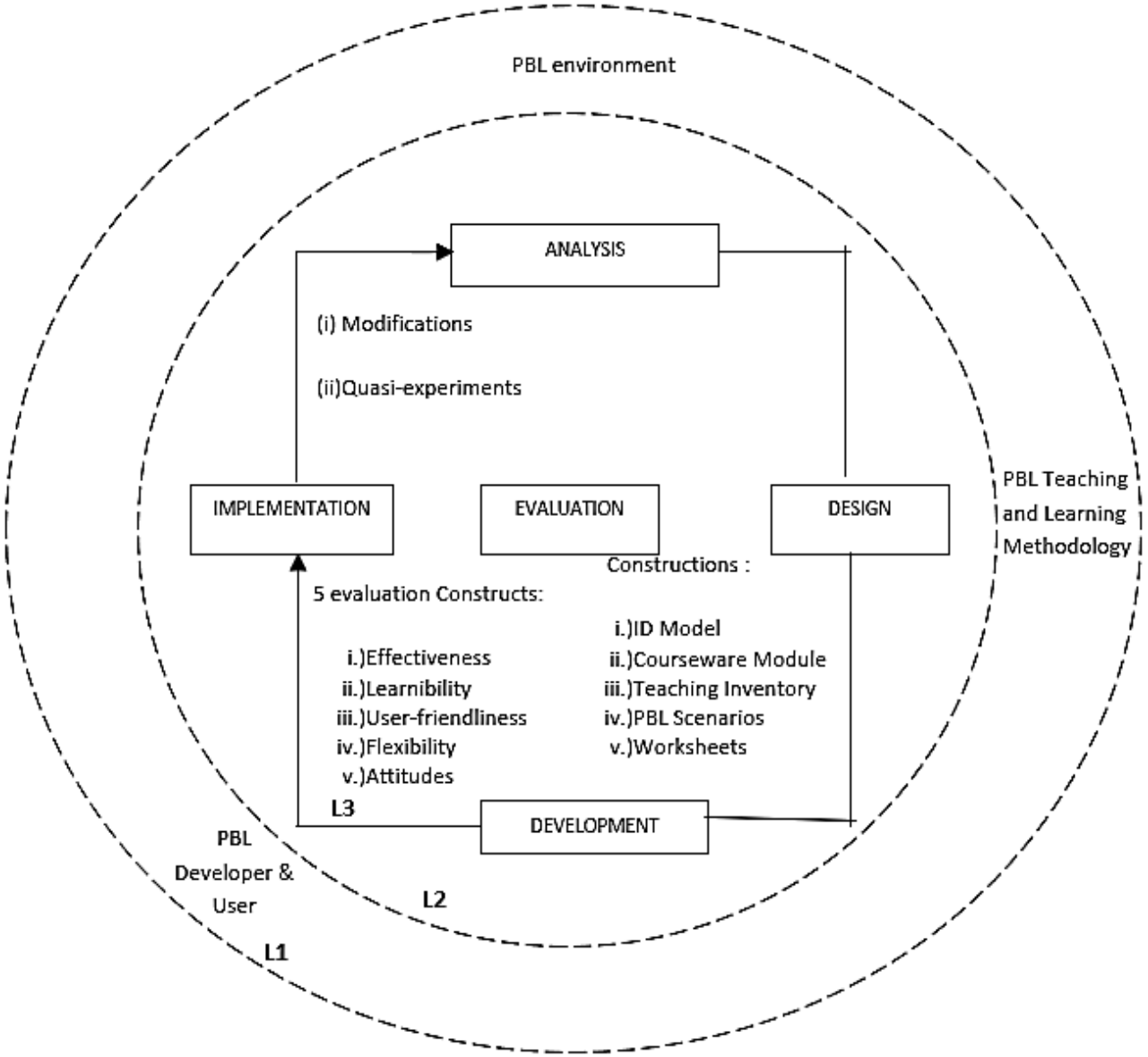

Fig. 1. C²HADAM life cycle model (KHC²HADAM)

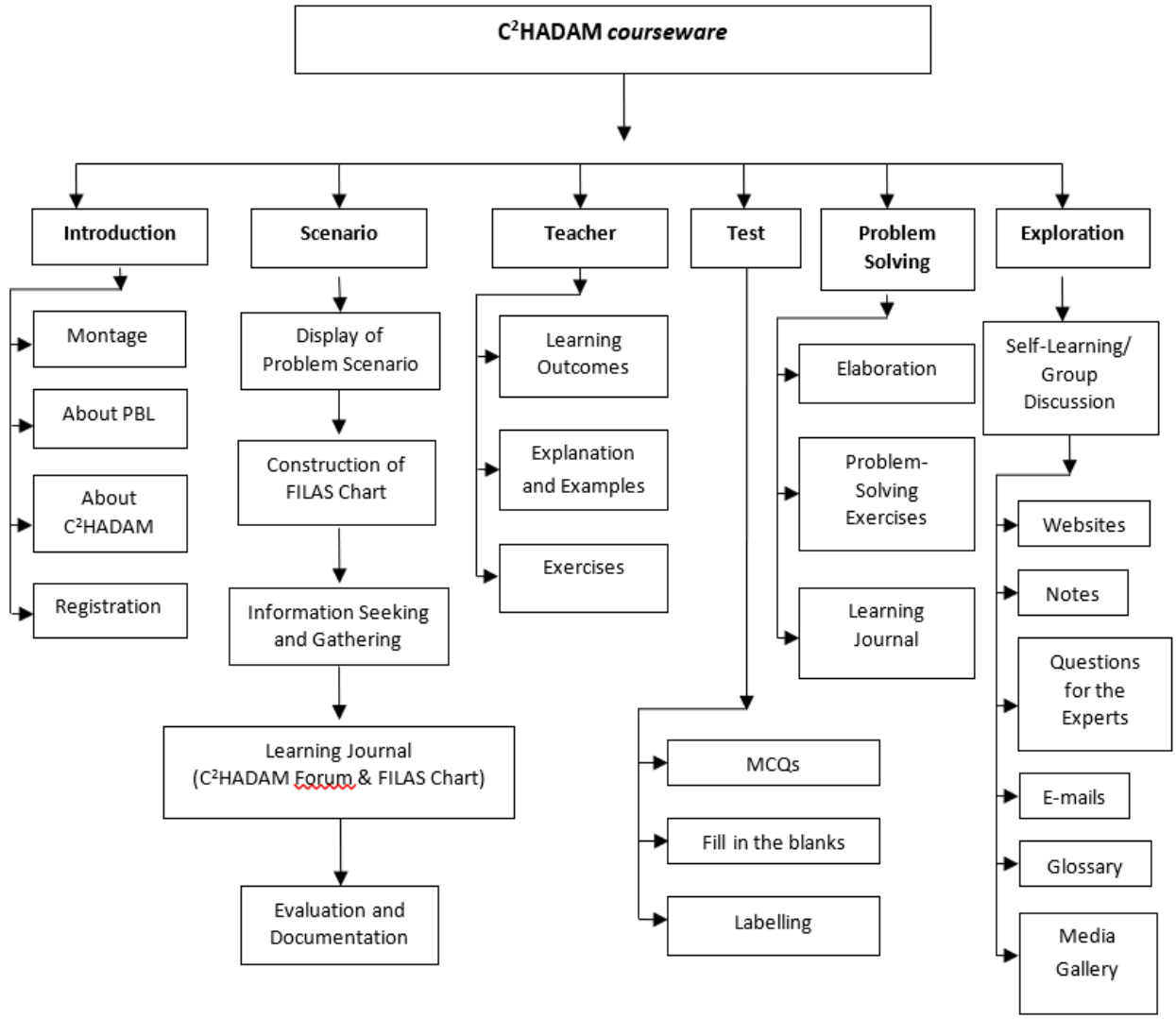

Fig. 2. Modules and submodules of C²HADAM courseware

3. Evaluating the Effectiveness Construct of the C²HADAM Multimedia Package Application

This section presents the findings from the evaluation on the effectiveness construct of the courseware application. The results are gathered from a study case with 64 form two students of Malaysia Secondary School Section 24 (2), Shah Alam, Selangor as shows in Table 1. The evaluation on the effectiveness construct of the C²HADAM courseware application on the performance of Form Two Secondary school is conducted based on the following research question. Q1: Does the use of the C²HADAM multimedia package, with the Hybrid PBL approach, enhance the performance of the Form Two students in comparison with the conventional teaching and learning methodology on the same topic Nutrition?

Pre and Post Tests: A quasi-experimental design involves selecting groups without random assignment, making it crucial to control for biases to ensure validity. In this study, efforts were made to match the control and experimental groups based on prior knowledge, demographic factors, and academic performance. Pre-tests were conducted to assess baseline equivalence, ensuring that both groups started with similar levels of understanding. Additionally, stratified sampling was used to balance variables such as gender, socio-economic background, and previous exposure to the subject matter. To minimize bias, assessments were standardized, and blind grading was implemented. These measures strengthen the reliability of the study's findings. The quasi-experiment method

carried out on two groups of Form Two students: the Experiment Group (X1), who received the treatment by using the C^{2}HADAM multimedia package based on the Hybrid PBL approach, and the Control Group (X2), who received the conventional teaching and learning methodology on the same topic.

To measure the performance in terms of the pre and posttests scores between the two respondent groups, the X1 and the X2, the Dependent T-Test was applied. To evaluate the effectiveness of the C^{2}HADAM multimedia courseware, we employed a comparative analysis of pre-test and post-test scores from two groups of students studying the topic of Nutrition. The X1 comprised students who utilized the courseware, denoted by 'E1' through 'E34,' while the X2, taught through traditional methods, consisted of students labelled 'K1' through 'K30.'

Table 1
Demographic distribution of samples

Groups	Girls	Boys	Total
Experiment (X1)	16	18	34
Controlled (X2)	16	14	30
Total	32	32	64

The average improvements in test scores from both groups are presented. For the X1, an average increase of 28.60% is reported, while the X2 showed an improvement of 14.75%. Initial scores showed a slight advantage for the X2 with an average pre-test score of 29.8% compared to the X1 27.6%, a difference of 2.2%. Post-test results, however, indicated a higher average for the X1 at 56.17%, surpassing the X2 42.6%, with a notable difference of 13.58% between the two groups. A more granular look at the pre-test scores reveals that the lowest score in the X1 was 0%, while the X2 had a minimum of 15%. The highest scores in the pre-tests were 55% for the X1 and 45% for the X2. Post-test analyses indicated that the lowest score for the X1 rose to 30%, while the X2 had a low of 17.5%. The highest post-test score for the X1 reached 95%, significantly surpassing the X2 high of 70%.

Setting the pass mark at 40%, the X1 achieved a higher pass rate of 85% compared to 53.4% for the X2. According to Table 2, which outlines the distribution of post-test scores, 46.6% of students in the X2 did not meet the pass mark, in contrast to 17.6% in the X1. Additionally, while no students in the X2 scored in the excellent range (80-100%), the X1 had 11.8% of its students achieving such high marks. This data underscores the enhanced performance and understanding of students utilizing the C^{2}HADAM multimedia courseware. The finding reveals that majority of students from the X2 were not able to show a good grasp of the topic (14 out of 30 students obtained scores between 0-34). Conversely, the students from the X1, who adopted the teaching and learning using the C^{2}HADAM multimedia courseware, displayed a rather even distribution of performance.

Table 2
Ranges of scores in the post test

Scores	Experiment group (X_1)		Control group (X_2)		Total	
	No.	percentage	No.	percentage	No.	percentage
0-39	6	17.6	14	46.6	20	31.3
40-49	3	8.8	5	16.7	8	12.5
50-59	10	29.4	2	6.7	12	18.7
60-69	8	23.5	7	23.3	15	23.4
70-79	3	8.8	2	6.7	5	7.8
80-100	4	11.8	0	0	4	6.3
Total	34	100.0	30	100.0	64	100.0

4. Conclusions

This study explores the intersection of various educational theories namely constructivism, collaborative learning, and PBL with the design of the C^{2}HADAM multimedia courseware. The courseware, which focus on the subject of Nutrition, was employed in a PBL-oriented Science curriculum for a group of selected Form Two students. Key PBL elements such as simulations, problem scenarios, teamwork, and instructional support were instrumental in facilitating students' grasp of Nutrition as a scientific concept. To assess the effectiveness of the courseware, methods including interviews, checklists, and questionnaires were utilized. response from participants was overwhelmingly positive, indicating an improvement in learner performance with the use of the courseware. Consequently, the incorporation of the PBL technique suggests its potential for broader application in the education of various scientific subjects.

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