Enhancing Teaching and Learning of an Applied Mathematics Modeling Course using Project-Based Learning

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Abstract: *This paper proposes a project-based learning (PBL) model for the teaching and learning of an applied mathematics course: mathematical modeling of blood flow and drug delivery in the pulmonary tumour-induced capillary bed. In this model, firstly a hypermedia instruction software package, developed using Flash and C#, is used to introduce to students the basic concepts and technologies related to blood flow and drug delivery in the capillary bed. Then the instructors present workshops to analyze the complex phenomena in the vascular system with an emphasis on the pulmonary capillary bed, and to give an overview of recent progress on mathematical modeling in the field. Several projects are then introduced to students with project aims clearly identified. Students are then divided into small groups with 3 to 4 students in each group. Each group chooses one project and works on it as a team. The group activities include design of project, plan, assigning of project elements to each group member, discussion of research problem and etc. Depending on the nature of the project, each student's task may include internet search of literature, construction of models, computing and analysis of results. After all project elements have been completed, members in each group get together to discuss the final results and write up a project report. Finally, each group presents a seminar and defense the report.*
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1. Introduction

Over the last decade due to the good feature of Project Based Learning (PBL) such as challenging students with real world problems and empowering students with responsibility for their own knowledge, a number of PBL research projects have been carried out worldwide [1, 4, 5, 6, 7, 8]. In PBL, students work actively in groups and build their own knowledge to solve real-life problems. A teacher becomes an instructor who gives only guidelines or direction of the subject. In 1992, Barrows [1, 2, 3] and William [12] developed a PBL model for medical students. Barrows' model combines problem statement and database analysis into an integrated process for medical students. His model can help interns to improve their diagnostic skills. In 1993, Stepein [10] developed a PBL model for mathematics, science, and social studies classes at elementary and secondary levels. It was found that PBL increased students learning skill including problem-solving skill, literature searching skill, collaboration skill, and critical thinking skill [7, 8, 9, 11]. Students also become more responsible for building up their knowledge. Compared with the traditional lecturing, PBL model enhances the quality of student learning in subject matter and fostering deeper learning.

This paper presents a project-based learning (PBL) model for the teaching and learning of an applied mathematics course: mathematical modeling of blood flow and drug delivery in the pulmonary capillary bed. The model consists of four basic components including introduction of basic concepts and technology by a hypermedia package, deeper learning of theories through workshops, enhancement of understanding on the subject and application through working on projects and project reporting, seminar presentation and assessment. The details of these components are presented in the following sections.

2. Learning of Basic Concepts and Technology by a Hypermedia Software Package

A hypermedia software package has been developed, using multimedia developing tool FLASH and C#, to challenge and guide students to learn the basic concepts and technologies involved in the subject through interaction with computer. This package presents the basic concepts and technologies, step by step, followed by a set of questions after each step. The questions are designed to keep students' focus and interests on the subject and to help students to self-check the quality of their learning outcomes.

The package begins with an overview of cardiovascular system with emphasis on the pulmonary capillary bed, followed by a number of questions. Figure 2.1 shows a typical set of questions which were designed for students to check whether they can correctly identify each of the eight key components of the pulmonary circuit system. Students are asked to view the diagram first, and then write the name of each of the eight components on the right column (your answer) or choose a right name from the left column then drag and drop it into the row on the right column one by one. To check the answer, students click on the "Check the answer" button to display symbols '✓' and '✗'in front of the right and the wrong answers, respectively. Students can also display the correct answer by clicking on "The correct answer" button.

The package then uses Flash animation display to describe the flow of blood in the capillary beds and the exchange across a capillary. Figures 2.2 and 2.3 are two typical snapshots taken during the animation display. Figure 2.2 gives the flow direction of blood, while Figure 3 shows the phenomenon of gas exchange across a capillary.

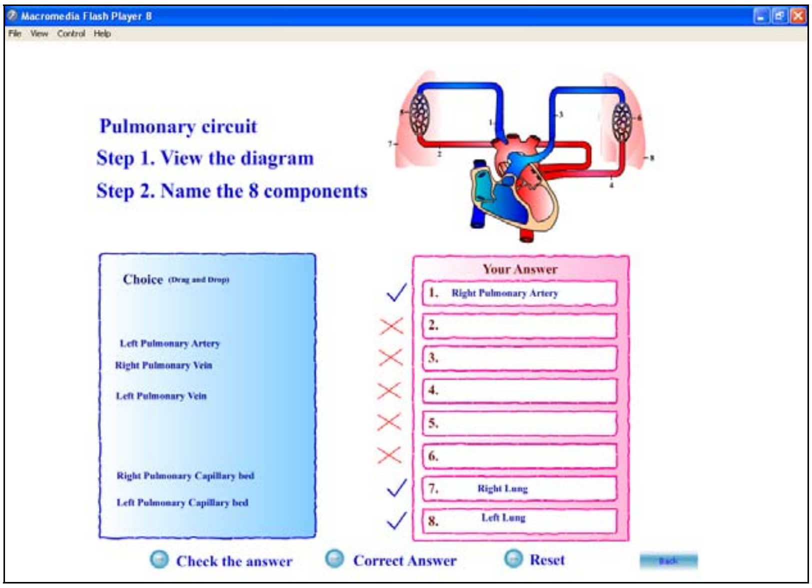


Figure 2.1 A typical set of questions on pulmonary circuit [7]

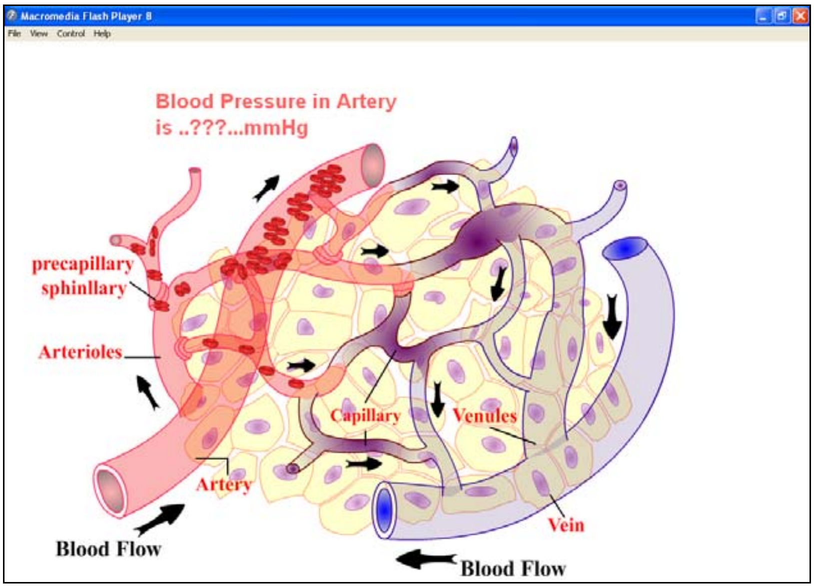


Figure 2.2 Blood flow in capillary bed

After showing the blood flow in capillary beds, a set of questions are given. Figure 2.4 shows a typical question for students to self-check their knowledge about the direction of blood flow in the cardiovascular system. In this question, students are asked to examine the three given diagrams and then click on the diagram which represents the real human cardiovascular system. Figure 2.5 (a) and (b) are the snap-shorts of animation showing the growth and the spread of cancer cells, respectively. Cancer cells or malignant tumours usually grow faster than normal cells and spread to other parts of body via blood circulatory.

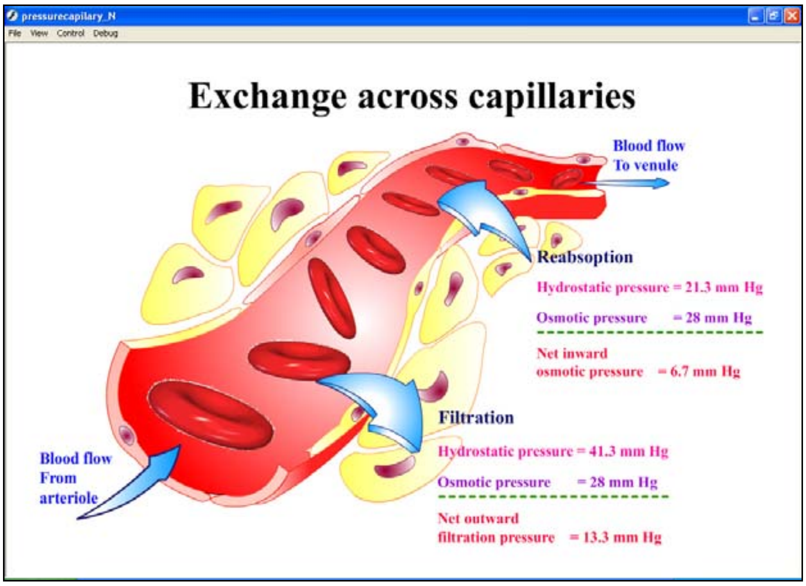


Figure 2.3 Phenomena of exchanges across a capillary

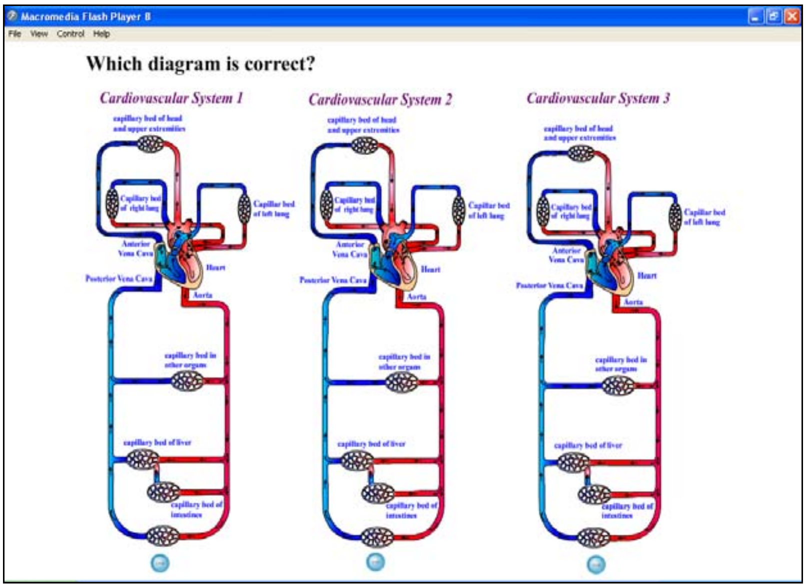
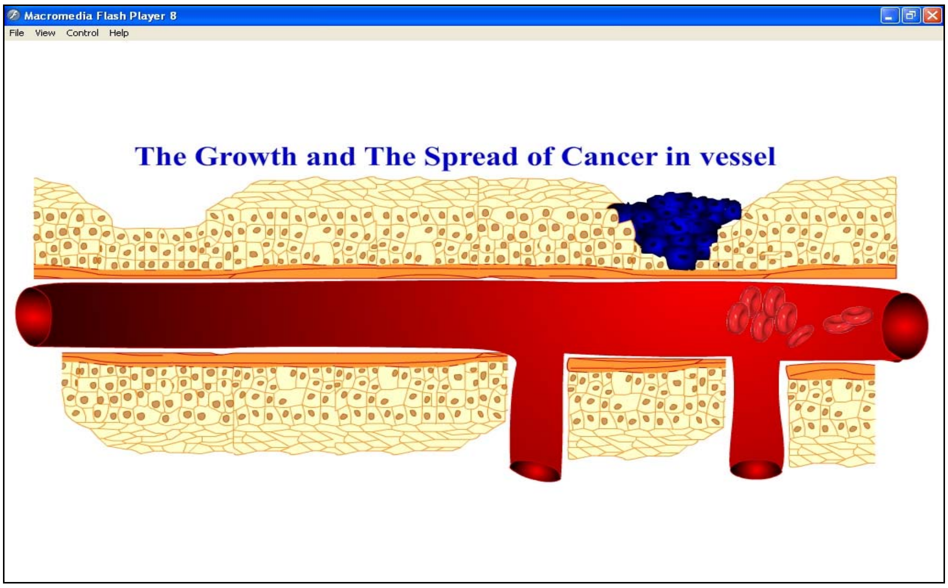


Figure 2.4 A typical question on blood flow in cardiovascular system [7]

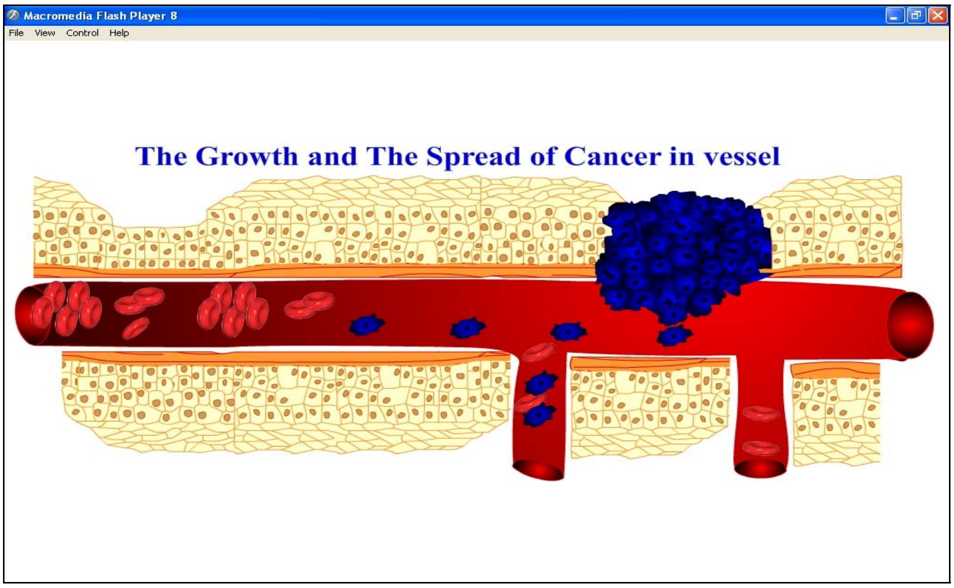
3. Learning of Theories Through Workshops and Setting of Projects

After introducing the basic concepts and technologies to the students via the hypermedia instruction software package, two workshops are held in week two to present the existing theories and recent research work on several topics at certain depth. The topics include blood flow behaviour, technology of drug delivery, tumour growth and cancer chemotherapy.

In the workshops, firstly the existing theories and methods for each topic are presented by the instructor. Then a brief introduction of recent research work in the field is given, followed by free questioning and discussion. For example, for the topic of blood flow behaviour, the instructor first describe that blood is a fluid consisting of red blood cells, white blood cells, water and numerous dissolved materials including proteins, lipids, carbohydrates, electrolytes and etc. Then the instructor presents the mechanical properties of blood followed by existing constitutive models including the Carreau model, Power law model and etc. Questions are then raised by the students about the percentage of water in blood, the size of red blood cells and white blood cells and etc.



(a)



(b)

Figure 2.5: (a) and (b) show the growth and the spread of cancer in vessel, respectively.

At the end of the workshops, a number of projects are issued for students to undertake. The following lists some projects:

(i) Blood flow behaviour and its constitutive models
(ii) Technology of drug delivery and its modeling
(iii) Mathematical modeling of tumour growth
(iv) Optimal control of drug delivery in cancer chemotherapy

Students are then divided into groups. Each group consisting of 3-5 students chooses one project from the above topics and works on the project as a team.

4. Deeper Learning Through Project Undertaking and Reporting

Each team is required to complete the chosen project within 4 weeks. The project work includes discussion among the team members, search of literature, mathematical formulation, computing and analysis, and report writing. Students are asked to play an active role in initiating their project with the help of a list of induced questions. Each group makes discussion to design the draft of the project report. They are requested to study the topics covered in the project in detail by using software and web technology. For example, for the blood flow behaviour project, the following questions were given to help students to design their project:

(i) Can you explain the direction of blood flow around the body?
(ii) Draw the diagram of vessel network and the direction of blood flow through the vessel.
(iii) Can you explain and draw the diagram of the structure and its function?
(iv) Can blood travel via poro-elastic layer of arterial wall?
(v) In what case, Human blood can be assumed as an incompressible Newtonian fluid, and as Non-Newtonian fluid?
(vi) Why blood can be modelled as a continuum medium? Under what conditions, Newtonian model gives reasonable approximation?
(vii) What are the governing equations for blood flow in the luminal region and in poro-elastic wall?

Every student has to record ideas, plans, designs, revision, solutions and questions of their own in the design/idea book which can be used for checking the progress of student during the project.

During the project process, the project work is divided into several components. Each member takes responsibility for one component. All results are shared at the end. Every project member then brainstorms and discuss within their group to write a project report based on their team work. The project report is required to include the following elements: (1) Project title, (2) Abstract, (3) Objectives of the project, and (4) Report of result (heading based on objectives).

5. Seminar and Assessment

After completing the project, a 45-minutes seminar will be held for each project for students to present their results to their classmates. The seminar will include 30 minute presentation by the students working on the project and 15 minute discussion for other students to ask questions or make comments.

Assessment will be made based on 3 components: (i) project report 40%, (ii) seminar and discussion 20% (iii) short test 40%. The short test will base on both the materials presented on the workshops and the materials presented by students in seminars. This is to encourage all students to involve in all workshops and seminars and to gain knowledge from all the projects undertaken, not only from those undertaken by the student himself or herself, but also from those undertaken by others.

6. Discussion and Conclusion

A hypermedia instruction software package is developed and used to introduce the basic concepts and technologies related to blood flow and drug delivery in capillary beds. The participants in this study are undergraduate students in the applied mathematical modelling course. We have developed an efficient PBL model consisting of four main components: (i) introduction of basic concepts and technologies by hypermedia software; (ii) workshops and setting of projects; (iii) project undertaking and reporting, and (iv) seminar and assessment. The model is used to drive and guide students to effectively learn mathematical modelling of blood flow and drug delivery in the pulmonary capillary bed. The model offers many advantages over the traditional teaching-learning mode, including enhancing students' motivation of learning, improving students' self-learning ability, preparing students for research, and improving students' oral presentation and written report skills.

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