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Dental Students' Attitude towards Problem-Based Learning before and after Implementing 3D Electronic Dental Models

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Abstract**—**Objectives: In recent years, the Faculty of Dentistry of the University of Hong Kong have extended the implementation of 3D electronic models (e-models) into problem-based learning (PBL) of the Bachelor of Dental Surgery (BDS) curriculum, aiming at mutual enhancement of PBL teaching quality and the students' skills in using e-models. This study focuses on the effectiveness of e-models serving as a tool to enhance the students' skills and competences in PBL. Methods: The questionnaire surveys are conducted to measure 50 fourth-year BDS students' attitude change between beginning and end of blended PBL tutorials. The response rate of this survey is 100%. Results: The results of this study show the students' agreement on enhancement of their learning experience after e-model implementation and their expectation to have more blended PBL courses in the future. The potential of e-models in cultivating students' self-learning skills reduces their dependence on others, while improving their communication skills to argue about pros and cons of different treatment options. The students' independent thinking ability and problem solving skills are promoted by e-model implementation, resulting in better decision making in treatment planning. Conclusion: It is important for future dental education curriculum planning to cope with the students' needs, and offer support in the form of software, hardware and facilitators' assistance for better e-model implementation.

Keywords**—**Problem-Based learning, curriculum, dental education, 3-D electronic models.

I. Introduction

MODIFICATIONS of dental education curriculum corresponding to the changes in modern dentistry are essential for sustained development of the dental faculty. 3D electronic models (e-models) are digital records of patients' oral conditions reproduced with the aid of 3D imaging [1]. 3D e-models serve as an alternative diagnostic tool to traditional plaster models and a teaching apparatus for patient-dentist communication in dental clinics [2]. Faculty of Dentistry of the University of Hong Kong have implemented 3D study e-models into the curriculum of BDS with supporting online virtual resources [3]. Blended learning using e-models has now been extended to PBL tutorials of BDS students. To which extent the students' learning experience has been enhanced by the features of the technology is hence important for further blended PBL curriculum planning [4].

PBL is an interactive and student-oriented learning method which requires the students to solve problems through self-directed learning [5], peer discussion and facilitation from a facilitator in the tutorial group [6]. The problems are complex and have more than one well-reasoning solutions. The facilitator's role in PBL is to guide the students in their analyzing and reasoning process instead of giving direct answers as done in traditional didactic teaching. It gives the students an opportunity to utilize the knowledge they have acquired in self-directed learning and collaborative learning so as to develop their skills of independent thinking, decision making, and clinical problem-solving [7]-[10]. Moreover, an important mission of PBL is to prepare the students to be lifelong self-directed learners [11], so that they could transfer and integrate their knowledge and skills to new problems in the future [12]. Using e-models in PBL helps the students to adapt better to current trend of digitalizing clinical records, and PBL provides a great variety of different learning outcomes with the aid of different implementations [13]. The method of assessing effectiveness of different PBL implementations should therefore be adjusted according to targeted outcomes of the implementations [14]. The aim of this study is to investigate whether using 3D e-models can change the students' learning perspectives in PBL. A questionnaire modified from existing studies in PBL in literature is used to measure changes in the students' attitude and study habits after using e-models in PBL [15]-[17].

II. Materials and Methods

The study is approved by the Institutional Review Board of the University of Hong Kong (Reference Number: UW 16-494). The e-models and their software used in PBL are uploaded to the learning management system [18], allowing the students to download freely with permission from the company of the e-models. The questionnaire surveys are conducted before and after the blended PBL tutorials.

The questionnaire used in this study consists of four parts. The questions in the first part are focused on the students' demographic information such as gender, age, and previous learning experience. The questions in the other three parts measuring the students' attitude towards blended PBL tutorials are modified from PBL Questionnaire (PBLQ) [15], PBL encouragement questionnaire (PBLEQ) [16], and PBL Attitudinal Instrument (PBLAQ) [17]. The questions in part

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two are related to cultivation of the students' skills in self-directed learning orientation and group collaboration. This part adopts thirty questions in PBLQ classified into four sub scales, i.e. "Use of multiple sources of learning", "Readiness for self-directed learning", "Appreciation of group/peer learning" and "Teamwork". The questions in part three adopt nine questions in PBLEQ aimed at measuring the extent to which the students' competencies in independent thinking and problem-solving had been improved. Due to overlapping of the questions in the reference questionnaires, the questions in the last part only include four questions in PBLAQ with an extra question "I would like to see all the courses taught in the PBL format" to measure the students' general attitude and expectation towards PBL before and after e-model implementation.

In order to have a more responsive, reliable and valid measurement without any subjective or statistical weighting on ratings of the elements, all of the questions from part two to four are singularized using visual analogue scale (VAS) [19]. A 100 mm horizontal line standing for 10 scores with two anchor points at two extremes of the line stating "Strongest disagree" and "Strongest agree" is used to measure continuous response of the students. The students are asked to make a vertical line along the horizontal line at the place that best represents the degree of their agreement to the statement. Scores ranging from 0.0 to 10.0 are then obtained by measuring horizontal distance in millimeter from anchor point "Strongest disagree" to interception of the lines. Means and standard deviations (SD) of the students' responses to the questions are calculated separately for two datasets collected before and after e-model implementation in PBL. T-tests of the scores in these two datasets are used to analyze the students' attitude change after e-model implementation in PBL. All statistical tests are two-tailed and the level of statistical significance is set at 0.05. All statistical analyses are performed using SPSS, version 23.0 (IBM Corp., Armonk, NY, USA).

III. Result

A. The Students' Personal Background

50 fourth-year BDS (BDS IV) students were invited to complete the questionnaire at the start and end of the blended PBL course. Response rate of either questionnaire surveys is 100%. Mean age of the students is 23.34 years old. 42% of the students are boys and the others are girls (see Fig. 1). 66% of the students are enrolled in BDS program through Joint University Programmes Admissions System (JUPAS) or the subsystem Early Admission Scheme of JUPAS. The highest educational level of the majority of the students (74%) is secondary school. English is the main teaching language in most of the students' previous education while Chinese is the students' major communication language with friends and at home. The individual average times for PBL preparation before and after e-model implementation are 5.63 and 7.08 hours per week respectively, with statistical significance ($p = 0.044 < 0.05$) found in its t-test.

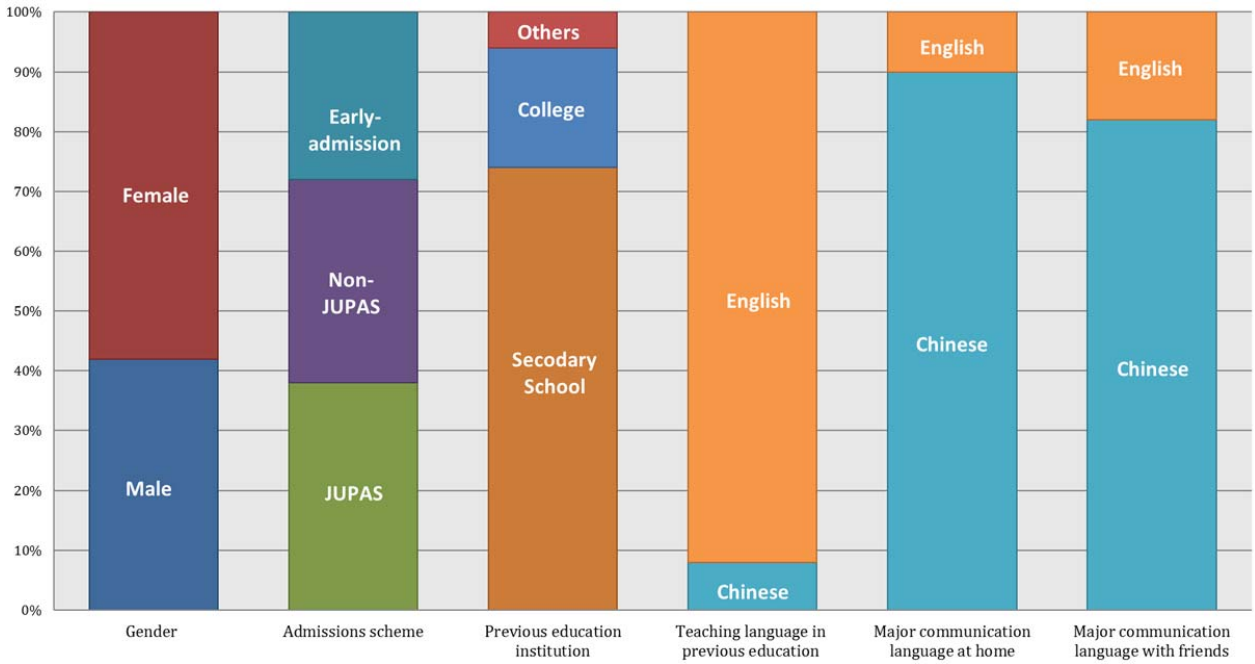

Fig. 1 Distribution of the students' characteristics (N = 50)

TABLE I
THE STUDENTS' AGREEMENTS TO THE CULTIVATION OF THEIR SKILLS IN SELF-DIRECTED LEARNING ORIENTATION AND GROUP COLLABORATION BEFORE AND AFTER THE E-MODEL IMPLEMENTATION IN THE PBL

Item No.	Item description	Before	After	
		Mean (SD)	Mean(SD)	Change in means
	Use of multiple sources of learning			
A1**	I am ready to learn without the help of traditional lecture	8.36(1.33)	9.06(1.19)	+ 0.70
A2**	I am ready to learn with the help of tutor feedback	8.14(1.77)	7.18(1.84)	- 0.96
A3	I am ready to acquire information through internet search	7.02(1.72)	7.44(1.60)	+ 0.42
A4*	I am ready to acquire information by reaching out to others	7.55(1.60)	6.97(1.60)	- 0.58
A5	I am ready to learn through my own observation	6.97(1.56)	7.14(1.73)	+ 0.17
A6	I am ready to learn experience	7.67(1.74)	7.75(1.40)	+ 0.08
A7	I can use my personal experience to facilitate new learning	7.25(1.94)	7.68(1.22)	+ 0.43
A8	I can use what I learned from other courses to facilitate new learning	6.89(1.66)	7.02(1.89)	+ 0.13
	Readiness for self-directed learning			
A9	Freedom in deciding what I am going to learn fits better with my learning needs	6.24(1.67)	6.67(1.95)	+ 0.43
A10	Getting to know an area through my own exploration is satisfying	6.67(1.51)	6.73(1.55)	+ 0.06
A11	I talk initiative to assess my learning needs and formulate my learning goals	6.73(1.65)	6.79(1.25)	+ 0.06
A12	When I run into a problem, I am ready to look for relevant resources	7.16(1.12)	7.18(1.45)	+ 0.02
A13	I am ready to evaluate the information I get	6.71(1.36)	6.95(1.32)	+ 0.24
A14	I am ready to apply knowledge to new problem situation	6.65(1.46)	6.79(1.41)	+ 0.14
	Readiness for group/peer learning			
A15	Exchange of information and opinion in group provides good stimulation	7.36(1.36)	7.42(1.62)	+ 0.06
A16	We can learn faster with more people sharing the learning tasks	6.91(1.94)	6.95(1.90)	+ 0.04
A17	I would prepare relevant information for group sharing	7.04(1.27)	7.38(1.60)	+ 0.34
A18	I know how to contribute in group learning situation	6.91(1.49)	7.08(1.53)	+ 0.17
A19	Discussion with others would enhance my understanding of the subject	7.31(1.53)	7.51(1.67)	+ 0.20
A20	Group emotional support would enhance my learning motivation	7.14(2.06)	6.71(1.47)	- 0.43
A21	I am ready to lead discussion	6.00(1.83)	6.34(1.86)	+ 0.34
A22	I think group conflict is best handled by the member themselves	6.85(1.77)	6.83(1.46)	- 0.02
	Team work in project			
A23	I am ready to explore conflicting ideas	6.75(1.61)	6.73(1.31)	- 0.02
A24	I am able to accept and respond to feedback/criticism gracefully	7.30(1.66)	7.42(1.42)	+ 0.12
A25	I am ready to give feedback to others	6.59(1.73)	6.55(1.64)	- 0.04
A26*	I could recognize the strengths and weakness of each in a group learning process	6.28(1.33)	6.81(1.39)	+ 0.53
A27	I am ready to compromise with others to come to joint decision	7.10(1.46)	6.86(1.19)	- 0.24
A28	I am punctual	7.67(2.10)	7.83(1.62)	+ 0.16
A29	I am ready to change my perception of the problem with new information brought in.	7.18(1.28)	7.28(1.36)	+ 0.10
A30	I am ready to contribute my best in a team project	7.10(1.41)	7.24(1.42)	+ 0.14

* Significance at p-value < 0.05
** Significance at p-value < 0.01

TABLE II
THE STUDENTS' AGREEMENTS TO THE CULTIVATION OF THEIR COMPETENCIES IN INDEPENDENT THINKING AND PROBLEM-SOLVING BEFORE AND AFTER THE E-MODEL IMPLEMENTATION IN THE PBL

Item No.	Item description	Before	After	
		Mean(SD)	Mean(SD)	Change in means
B1	Critical thinking	6.91(1.27)	7.18(1.49)	+ 0.27
B2	Problem-solving	6.91(1.55)	6.95(1.30)	+ 0.04
B3	Study for examinations	5.42(1.91)	5.77(2.16)	+ 0.35
B4	Formulation and definition of problems	6.22(1.72)	6.24(1.65)	+ 0.02
B5	Study outside textbooks	6.68(1.71)	7.12(1.73)	+ 0.44
B6	Study of details	5.81(1.57)	6.25(2.09)	+ 0.44
B7*	Decision-making	5.95(1.59)	6.60(1.55)	+ 0.65
B8	Study of literature for problem-solving	6.30(1.66)	6.44(1.91)	+ 0.14
B9	Ability to argue systematically pro/contra	6.30(1.69)	6.77(1.54)	+ 0.47

* Significance at p-value < 0.05

TABLE III
THE STUDENTS' GENERIC ATTITUDES AND EXPECTATION AFTER THE E-MODEL IMPLEMENTATION BEFORE AND AFTER THE E-MODEL IMPLEMENTATION IN THE PBL

Item No.	Item description	Before	After	
		Mean (SD)	Mean(SD)	Change in means
	Generic Attitude			
C1	PBL is a valuable experience	6.55(1.81)	7.08(1.38)	+0.53
C2	PBL is a worthwhile method of learning	5.93(1.94)	6.73(1.46)	+0.80
	Generic expectation			
C3	I would like to have more opportunities for PBL	5.43(2.05)	5.93(1.76)	+0.50
C4	I prefer PBL method rather than traditional-lecture method	5.05(2.04)	5.25(1.79)	+0.20
C5	I would like to see all the courses taught in the PBL format	4.30(1.89)	4.83(1.94)	+0.53

B. Agreement before and after the E-model Implementation

The mean score of the 23 out of 30 items in part two of the questionnaires increases after e-model implementation in PBL (see Table I). Four items, i.e. "I am ready to learn without the help of traditional lecture", "I am ready to learn with the help of tutor feedback", "I am ready to acquire information by reaching out to others" and "I could recognize the strengths and weakness of each in a group learning process" have an increase of more than 0.5 scores, showing significance in t-tests with p-values 0.002, 0.002 (<0.01), 0.026 and 0.036 (<0.05) respectively. The mean score of all nine items in part three of the questionnaires increases after use of e-models in PBL (see Table II), four of which show greatest improvement and have increased by more than 0.4 scores. They are "Decision- making", "Ability to argue systematically pro/contra", "Study of details" and "Study outside textbooks", but only "Decision-making" shows statistical significance in t-test with p-value 0.028 (<0.05). Furthermore, the mean score of all five items in part four of the questionnaires increases after use of e-models in PBL (see Table III). No statistical significance is found in t-test of the items in this part.

IV. Discussion

The students' understanding of educational goals of PBL is the key to whether these goals can be achieved [20]. The general increase of these questionnaire item scores shows that assistance of e-models has positive effect on the student's perceived learning outcomes such as targeted skills and competences in PBL. The introduction of e-models to replace plaster casts in PBL tutorials, and software support of e-models in form of online resources are two major changes our study has made to the educational setting in PBL tutorials. Besides patient information display function of traditional solid plaster casts, e-models and their software have extra functions such as instantaneous and accurate dimension measurement, treatment option simulation, and virtual duplication and superposition of the models. Moreover, online support allows the students to download e-models from online learning system any time and anywhere, rather than limited amount of study time with traditional solid plaster casts in PBL tutorials only. This convenience in accessing implemented e-model study resources also makes changes to the student's study habits, manifesting as a significant increase of PBL preparation time by 1.45 hours per week. Through integrated analysis of the students' behavior and attitude changes, we are able to obtain a better understanding of the students' needs.

Since the students will face all kinds of different problems in their future clinical environment, training them to be self-directed learners is an important goal of our BDS curriculum. One of the significant changes brought by PBL is that PBL promotes active learning rather than passive learning. In traditional lectures, how much a student can learn depends mostly on the instructor's knowledge and presentation skills. In PBL, however, the students could access multiple learning sources as well as learn from other students during group discussion. Among the items related to the students' self-directed learning skills, significant decrease is found in 3 scores, i.e. the students' agreement level to the statements "I am ready to learn with the help of traditional lecture", "I am ready to learn with the help of tutor feedback" and "I am ready to acquire information by reaching out to others". Meanwhile, all of the other scores show increase after adding e-model to the curriculum. This contrast demonstrates that the students are better at gathering useful information and extracting knowledge out of it through self-directed learning, hence their dependence on direct answers from instructors has become less. Competence is the ability to use a set of knowledge and skills to achieve a goal. Apart from analysing the students' skill levels, changes in the students' attitude towards their competence levels should also be monitored, interpreted and mutually supported. Before e-models are implemented, it was a challenge to precisely describe patients' oral condition in words, especially when fine measurements were needed. The e-models, however, contain all information related to patients' dental condition, hence can facilitate students' problem analysis and treatment planning. Items "Study outside textbooks" and "Study of details" as two aspects of the students' competence have increased by more than 0.4 scores, indicating that e-models are better sources of detailed information hence they can improve self-directed learning efficiency. Although the information e-models provide to every student is the same, each student may find a different way to comprehend and make use of it. In this process, original ideas are developed and abilities to find specific information to support these ideas are trained. Unsurprisingly, independent thinking becomes an essential element of problem-solving. This also explains why the items "I am ready to acquire information through internet search", "I can use my personal experience to facilitate new learning" and "Freedom in deciding what I am going to learn fits better with my learning needs", i.e. indicators of self-directed learning ability, have all increased by more than 0.4 scores after e-model implementation in PBL.

Thanks to e-model's duplication and simulation functions, the students can simulate different treatment options and use the provisional outcome to help them finalize treatment plan. Manufacturing and duplication of new models are no longer time-consuming, and the tremendous manpower and material cost in traditional model casting can now be saved. In addition, e-model superposition is a unique function to allow model comparison [21]. It is especially useful for students to see differences before and after treatment, or to find differences between their own e-model and that of other students. Differences in treatment plans and simulated treatment outcomes are strongly dependent on the students' basic knowledge and closely related to the students' treatment philosophy. Therefore, this superposition function helps the students to recognize their own strength and weakness in group learning environment, and trains them to optimize their treatment plans by reasoning and logical thinking. This hypothesis is supported by significance found in items related to the students' collaborative learning skills, i.e. the item "I

could recognize the strengths and weakness of each in a group learning process" which has increased by 0.53 at $p<0.05$, and the item "Ability to argue systematically pro/contra" which had 0.47 increased scores. All of the factors mentioned above should work together to achieve a common goal, a goal we share as the cornerstone of PBL curriculum, that is to enable the students to make the right and most appropriate decision in all kinds of clinical situations. Apparently e-models can bring us one step closer to this goal, shown by highest increase in the score of item "Decision-making" with statistical significance in t-test (p-value < 0.05).

Although no statistical significance is found in results of the last part of the questionnaire, a general increase of item scores in this part illustrates the students' satisfaction of blended PBL. Increase of the scores of items "PBL is a valuable experience" and "PBL is a worthwhile method of learning" shows that e-models and their analytic software add value to the students' PBL learning experience. While increase of the remaining items reflects the students' appreciation of this modified teaching strategy and suggests that they expect further use of it in the future. On the other hand, e-model implementation shows little impact on encouragement of the students' collaborative learning skills. Since these skills are also important for the students' study and future clinical work [22], follow-up curriculum designers need to pay more attention on how to encourage group collaboration while the students focus on their own e-models. Facilitators can make use of e-models to teach in a more informative way, utilizing its clear and detailed visual aid as well as its eye-catching multiple functions. For example, facilitators can spend more time in demonstrating and sharing how to use e-models, in order to encourage more interactions and communication among the students. The faculty also needs to consider whether there will be enough hardware support such as computers or screens in the PBL tutorial rooms as it will strongly affect the students' learning experiences if e-models will be routinely used. Although e-models have shown to be working well and can cope better with the students' needs, financial restraints and resource limitations should also be taken into consideration [23], [24].

As blended PBL is a new teaching strategy in the Faculty of Dentistry of The University of Hong Kong, limited number of courses as well as limited number of students utilized this strategy with e-model as a teaching supplement. Although there is positive finding in this study, the small sample size limits validity of significance in statistical analysis. Follow-up studies involving more courses and students, as well as covering longer period of observation time, e.g. starting from the first year of the students' BDS program, may improve validity and reliability of the results statistically. Since the questionnaires used in this study are designed specifically to target goals of PBL teaching, the results have limited implication on other blended learning environment. Hence future studies may include open-ended questions about the students' perception, additional questionnaire for facilitators, and assessment of the students' learning outcomes to have a broader view and deeper understanding of the outcomes. Flipping the stimulator and effector may be another direction of further studies, i.e. to study the impacts on students' skills of using e-models under the influence of PBL settings.

V. Conclusion

The general increases of item scores show positive changes of the students' targeted skills and competences in PBL under the influence of e-model implementation in PBL. The students may regard that e-model implementation adds value to PBL tutorials and they may look forward to more tutorials in this blended PBL format. Six items, i.e. "Students' time for PBL preparation", "I am ready to learn with the help of traditional lecture", "I am ready to learn with the help of tutor feedback", "I am ready to acquire information by reaching out to others", "I could recognize the strengths and weakness of each in a group learning process", and "Decision-making" show statistical significances in t-tests. It reinforces validity of using e-models as an informative tool to help the students in learning and preparing for PBL tutorials. Online virtual resources and analytic software of e-models allow the students to put their own knowledge and experience into exercise and have their ideas elaborated, thus promoting the student's self-directed learning skills in acquiring and reorganizing information. Besides, the convenience of e-model comparison trains the students' ability in analyzing Pro's and Con's of different treatment options as well as finding their own strengths and weakness in group discussions. Eventually, e-model implementation promotes the students' independent thinking and problem-solving competences especially in decision-making. In general, this study shows the potential of e-models as an effective tool to assist developing the students' competences and skills under PBL environment. For future curriculum design, facilitators should offer more demonstration and assistance to help the students to train their collaborative learning skills. The faculty should also promote this new teaching strategy with sufficient software and hardware support, and keep on monitoring the students' learning outcomes and attitudes to blended PBL for sustained faculty development.

Disclosure

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