Qualitative and quantitative analysis of the students’ perceptions to the use of 3D electronic models in problem-based learning

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Abstract: Faculty of Dentistry of the University of Hong Kong has introduced innovative blended problem-based learning (PBL) with the aid of 3D electronic models (e-models) to Bachelor of Dental Surgery (BDS) curriculum. Statistical results of pre- and post-semester questionnaire surveys illustrated compatibility of e-models in PBL settings. The students’ importance ratings of two objectives “Complete assigned tasks on time” and “Active listener”, and twenty-two facilitator evaluation items including critical thinking and group problem-solving skills had increased significantly. The students’ PBL preparation behavior, attentions to problem understanding, problem analysis, and learning resource quality were also found to be related to online support of e-models and its software. Qualitative analysis of open-ended questions with visual text analytic software “Leximancer” improved validity of statistical results. Using
e-model functions in treatment planning, problem analysis and giving instructions provided a method of informative communication. Therefore, it is critical for the faculty to continuously provide facilitator training and quality online e-model resources to the students.

**Keywords:** Dental education; Blended problem-based learning; 3D electronic models; Curriculum design; Leximancer

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1. **Introduction**

3D electronic models (e-models) is a diagnostic tool used in modern dentistry as a type of patient clinical record with better maintenance, retrieval and transferability than traditional plaster casts (Redmond, 2001). 3D study e-models have been adopted into dental education thanks to the evolutionary 3D image scanning and computer-aided design (CAD) technology (Joffe, 2004). Faculty of Dentistry of the University of Hong Kong has introduced virtual resources and online support of 3D e-models into blended problem-based learning (PBL) for curriculum of Bachelor of Dental Surgery (BDS) (Yang, Zhang, & Bridges, 2012). This new method have replaced the use of traditional plaster study models in PBL to assist the students in treatment planning (Whetten, Williamson, Heo, Varnhagen, & Major, 2006) and to help them adapt better to the fast-changing modern dental technology.

Different from the passive learning environment of traditional didactic way of teaching, PBL has reconstructed the learning environment into an active and student-centered one by utilising facilitated small group discussion and problem solving (Hmelo-Silver, 2004). It enhances individual student’s understanding of teamwork (Carlisle & Ibbotson, 2005), critical thinking ability (Tiwari, Lai, So, & Yuen, 2006), problem-solving skills, self-directed learning skills, transferable skills, as well as retention of knowledge and skills (Norman & Schmidt, 1992). The role of teaching staff in PBL has changed from a didactic lecturer to an interaction-oriented facilitator, influencing the students’ performance (Van Berkel & Schmidt, 2000) by providing collaborative construction of knowledge, guidance and assistance in group function (Ling & Loy-Pang, 2007). Various assessments in the process of teaching are hence critical to help the students to adapt to educational setting changes, and link their performance to specific learning outcomes (Fincham & Shuler, 2001). Student self-assessment aims to clarify PBL curriculum expectations and specific educational objectives for the students, so that
they can integrate course content into learning process more actively and responsively. In addition to evaluating student’s learning progress and promoting understanding of facilitator’s role, facilitator-assessment serves as feedback for future course adjustment and development of better facilitation (Stassen, Doherty, & Poe, 2001).

While implementing e-models, facilitators also concern about how to effectively use their pedagogical beliefs and facilitation skills (Haith-Cooper, 2000) to maintain proper group function, which might be interrupted by both introduction and demonstration of e-models and its software. Understanding compatibility of e-models and expectations of PBL is therefore important for future curriculum design which is based on student experience rather than financial constraint (Winning & Townsend, 2007) and resource needs (Azer, 2001). The aim of the study is to analyse the compatibility of e-models in PBL settings and the students’ perception of e-models. The questionnaire used in this study was modified from current questionnaires used in Faculty of Dentistry, the University of Hong Kong for student self-assessment and facilitator-assessment in PBL. They showed the faculty’s expectations in PBL teaching strategies. The student’s understanding of the faculty’s expectations in creating the mutual expectation (Kolmos, Du, Holgaard, & Jensen, 2008) was measured from their importance ratings of the items in the questionnaire. For testing the compatibility of e-models in PBL, the consistency of the mutual expectations to the PBL teaching strategies should be shown in both the pre- and post-questionnaire surveys before and after implementing e-models in PBL. Also, one open-ended question was included in the questionnaire to measure the students’ perception of e-models in PBL.

2. Methodology

The study was approved by the Institutional Review Board of the University of Hong Kong (Reference Number: UW 16-494). The e-models used in PBL were supported by the software O3DM® (Kriel, 2012) which was uploaded to online learning system, allowing the students to download freely with permission from the O3DM® Company in the entire PBL session. E-models served as one of the inquiry materials in PBL to provide the patients’ intraoral information for the case studies. The facilitators had to guide the students’ discussions by asking the trigger questions and assisting the students in the proper use of the inquire materials. Fifty fourth-year BDS students (divided into six groups of nine students) were invited to complete the pre- and post-test questionnaire about their perception of using e-models and their expectations of PBL. Pre-test questionnaire data was collected before the students’ first PBL tutorial to use e-models, while follow-up post-test survey using exactly the same questionnaire was conducted at the end of the last PBL tutorial of using e-models. The total length of the PBL sessions that the students in this study engaged in was two weeks.

The evaluation questionnaire used in this study was composed of four parts. The first part consisted of questions related to the students’ personal background and the time they spent for PBL preparation. 16 questions in the second part were focused on learning purposes of PBL, i.e. “Responsibility”, “Proper knowledge base”, “Well in reasoning” and “Communication well” and 12 specific objectives of these goals in the form of self-assessment. While the third part consisted of 35 questions for facilitator assessment, focusing on 7 goals of PBL teaching, i.e. “Display understanding of the role being a PBL facilitator”, “Promote group problem solving”, “Promote appropriate group function”, “Promoted effective evaluation”, “Facilitate your learning”, “Promote your critical thinking”, and “Promote your learning”. Visual analogue scales (VAS) were used for questions in the second and third part of the questionnaire to quantify the students’
answers. A 100-mm horizontal line with two anchor points at two extremes stating “Not important” and “Very important” was used to measure the student’s continuous response to the question. The students were asked to make a vertical line along the horizontal line at the place that best represented their perceived importance of the goal or objective. 1 mm in length of the horizontal line stands for 0.1 score of value. The final score ranging from 0 to 10.0 was then obtained by measuring the horizontal distance from the anchor point “Not important” to the interception of the lines. This method provided more responsive, reliable and valid measurement without any subjective or statistical weighting on rating elements (De Boer et al., 2004). The last part was an open-ended question which asks about the students’ perception of using e-models. The inclusion of open-ended qualitative question in the questionnaire was aimed at improving validity of statistical results and quality of suggestions to curriculum designers (Noesgaard & Ørngreen, 2015).

Two sets of data and feedback collected from the questionnaire surveys were then further analysed. Quantitative analyses were carried out for data in the first three parts of the questionnaire. Means and standard deviations of the question scores were calculated. T-tests were run to analyze changes after using e-models in PBL. Regression was run to find out association between students’ change of expectations and their learning experience in PBL after implementing e-models. All statistical analyses were performed using SPSS, version 23.0 (IBM Corp., Armonk, NY, USA). All statistical tests were two-tailed and the level of statistical significance was set at 0.05. Furthermore, visual text analytic software “Leximancer” was used for qualitative analysis of feedback in the last part of the questionnaire. “Leximancer” is a powerful text analytic software in thematic analysis of the text content by analyzing word occurrence and co-occurrence statistics (Smith & Humphreys, 2006). This provided a more systematic way to understand the students’ perceptions with an objective catalog of themes mentioned in the feedbacks, for the benefit of optimization of strategies with enhanced conceptual understanding of text data (Cretchley, Gallois, Chenery, & Smith, 2010).

3. Result

3.1. The students’ personal background

All fifty fourth-year BDS students had completed and returned the pre- and post-test questionnaires with 100% response rate. Mean age of the students was 23.34 years old. 21 of them (42%) are male students and 29 (58%) are female students (see Table 1). 66% students entered BDS through Joint University Programmes Admissions System (JUPAS) and 28% of them came from subsystem Early Admission Scheme of JUPAS. Most of the students (62%) came from local secondary schools in Hong Kong. The students’ weekly hours of preparation for PBL in total and on Internet increased from 5.63 to 7.08 and 2.45 to 2.78 respectively after using e-models (see Table 2). The students’ self-reported total time for PBL preparation before and after using e-models in PBL showed statistical significance in t-test (p = 0.044 < 0.05).

Table 1
The characteristics of the 50 students

<table>
<thead>
<tr>
<th>Student characteristics</th>
<th>Number (percentage)</th>
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<tbody>
<tr>
<td>Gender</td>
<td></td>
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</table>
Male 21 (42%)
Female 29 (58%)

**Admissions scheme**
- JUPAS† 14 (28.0%)
  - Early Admission Scheme 19 (38.0%)
  - Non Early Admission Scheme 17 (34.0%)
- Non-JUPAS

**Previous education institution**
- Local secondary school in HK 31 (62.0%)
- International secondary school in HK 1 (2.0%)
- Secondary school in mainland China 1 (2.0%)
- Overseas secondary school 4 (8.0%)
- College in HK 2 (4.0%)
- Overseas college 8 (16.0%)
- Others 3 (6.0%)

*Note. †JUPAS = Joint University Programmes Admissions System*

**Table 2**
Time for PBL preparation before and after the use of e-models in PBL

<table>
<thead>
<tr>
<th>PBL preparation</th>
<th>Mean hours per week (SD)</th>
</tr>
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<tbody>
<tr>
<td><strong>Time total</strong></td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>7.08 (4.49)</td>
</tr>
<tr>
<td>Before</td>
<td>5.63 (2.66)</td>
</tr>
<tr>
<td><strong>Time on internet</strong></td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>2.78 (1.98)</td>
</tr>
<tr>
<td>Before</td>
<td>2.45 (1.53)</td>
</tr>
</tbody>
</table>

*Note. *P*-value < 0.05*

3.2. The students’ importance ratings on the expectations in the student self-assessment of PBL

Mean score of the students’ importance ratings in self-assessment of PBL before and after using e-models was 6.84 and 7.19 respectively. All questions about goals (see Fig. 1) and related objectives (see Fig. 2) in this part had greater importance rating in post-test data compared to pre-test data. Two of the objectives, i.e. “Complete assigned tasks on time” (p = 0.031 < 0.05) and “Active listener” (p = 0.015 < 0.05) showed statistical significance in t-tests. In addition, two of the goals, i.e. “Well in reasoning” and “Communicate well”, and four of the objectives showed linear correlation between their
importance ratings and the students’ PBL preparation time on Internet, according to regression analysis in post-test data.

Fig. 1. The students’ importance ratings of the goals in the student self-assessment

Fig. 2. The students’ importance ratings of the objectives related to the goals in the student self-assessment

3.3. The students’ importance ratings on the expectations in the facilitator-assessment of PBL

Mean score of the students’ importance ratings in facilitator-assessment of PBL before and after using e-models was 6.41 and 7.11 respectively. All questions about goals (see
Fig. 3) and related objectives (see Fig. 4) in this part showed increased importance ratings in the post-test data. Five goals out of seven, i.e. “Promote group problem solving” ($p = 0.010 < 0.05$), “Promote appropriate group function” ($p = 0.045 < 0.05$), “Facilitate your learning” ($p = 0.037 < 0.05$), “Promote your critical thinking” ($p = 0.015 < 0.05$) and “Promote your learning” ($p = 0.013 < 0.05$), and seventeen objectives out of twenty-eight demonstrated statistical significance in t-tests. In regression analysis, objective “Ask you to evaluate the quality of learning resources used” showed linear correlation between its importance rating and the students’ PBL preparation time on Internet after using e-models in PBL.

Fig. 3. The students’ importance ratings of the goals in the facilitator-assessment

Fig. 4. The students’ importance ratings of the objectives related to goals in the facilitator-assessment
3.4. The students’ importance ratings on the expectations in the facilitator-assessment of PBL

Eight themes were extracted from the content of the students’ feedback in the last part of questionnaire. After taking into consideration concepts presented in the themes, related examples from the concept map (see Fig. 5) and tables of Leximancers' result, the extracted themes were then named “Comparing with solid plaster casts”, “The use in lab stages”, “Patient feeling”, “Computational support”, “Cost”, “Quality of models”, “Preparation of models”, and “Treatment planning”. The relationships of different themes were also shown in the concept map. Table 3 lists and summarizes the students’ perceptions of the themes accordingly.

Fig. 5. The Leximancer’s concept plot of students’ perception of using e-models showing in eight extracted themes
Table 3
Summary of the students’ perceptions of using e-models in eight themes of the Leximancer’s result

<table>
<thead>
<tr>
<th>Theme 1: Comparing with solid plaster casts</th>
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<tbody>
<tr>
<td>✓ No storage place is needed for e-models.</td>
</tr>
<tr>
<td>✓ E-models are convenient to be kept.</td>
</tr>
<tr>
<td>✓ E-models have no hygienic problem but solid plaster casts would be fractured, mottled, deteriorated, worn, broken, lost or be messy in a long-term storage.</td>
</tr>
<tr>
<td>✗ A good resolution monitor is required for the display of e-models.</td>
</tr>
<tr>
<td>✗ It is better to have the use of both e-models and plaster casts.</td>
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<table>
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<tr>
<th>Theme 2: The use in lab stages</th>
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<tbody>
<tr>
<td>✓ E-models are transferred to lab technicians or other dentists on referral more easily and quickly in the instant image format.</td>
</tr>
<tr>
<td>✓ Quicker communication to lab is achieved without waiting on plaster cast production and transference.</td>
</tr>
<tr>
<td>✓ Better communication is provided when team approach is needed.</td>
</tr>
<tr>
<td>✓ E-models aid in design and manufacture of plaster casts</td>
</tr>
<tr>
<td>✗ Extra scanning procedure is needed in order to create images of e-models.</td>
</tr>
<tr>
<td>✗ Extra computational skills of software like O3DM or CAD-CAM are required for the lab stages such as waxing of crowns and design of prosthesis, if not actual plaster casts are still needed for lab work.</td>
</tr>
<tr>
<td>✗ Dental lab may not support the system of e-models.</td>
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<tr>
<th>Theme 3: Patient feeling</th>
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<tbody>
<tr>
<td>✓ E-models are convenient and easy for the presentation facilitating the communication with patients.</td>
</tr>
<tr>
<td>✓ Preparation of e-models is more tolerable to patients in tooth scanning without pouring for dental impression.</td>
</tr>
<tr>
<td>✓ E-models give “Cyber” and “high tech” conception to patients.</td>
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<tr>
<th>Theme 4: Computational support</th>
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<tbody>
<tr>
<td>✓ Easier measurement and calculation of spacing are supported by the software of e-models.</td>
</tr>
<tr>
<td>✗ The computer generated analysis results of e-models required the support of computers and software.</td>
</tr>
<tr>
<td>✗ Large memory storage space required for the records of e-models.</td>
</tr>
<tr>
<td>✗ Maintenance of computers and anti-viral software are required for patient records in preventing data loss and protecting data privacy.</td>
</tr>
</tbody>
</table>

| Theme 5: Cost |
- The cost of plaster casts production and transference is lower.
- Scanning of the teeth of patients and turning it into digital data are expensive.
- The cost of installation and running of the supporting software of e-models is expensive.

**Theme 6: Quality of models**
- E-models show more accurate details.
- E-models show better appearance than actual plaster casts.

**Theme 7: Preparation of models**
- Easy copy function of e-models is convenient for dentists to compare the multiple models.
- E-models are environmental friendly.
- Mass production of plaster casts or production of prosthodontic appliances such as removable partial denture and fixed bridges will be realized by the application of 3D printing on e-models in future.

**Theme 8: Treatment planning**
- Treatment procedures on e-models are reversible by undoing or soft copying.
- Treatment procedures on e-models can be pinpoint.
- The expected treatment outcomes can be stimulated.
- Treatment planning is facilitated by accurate instruction and production of e-models.
- E-models show possible prosthodontic treatment options.
- E-models can be used to diagnostic wax-up treatment.
- E-models can simulate the tooth movement.
- E-models can have occlusal analysis.
- E-models cannot simulate as articulator in checking lateral excursion.
- Face-bow cannot be done.

**Note.** ✓ Advantage, ✗ Disadvantage, • Comment

### 4. Discussion

Although Faculty of Dentistry, University of Hong Kong has adopted PBL in BDS curriculum since 1998, methods of instruction have always been under modification based on changes in real-life clinic settings and longitudinal effectiveness of different strategies reported by other reviewers. Blended PBL was developed to enhance both PBL teaching effectiveness and integration of e-models in clinical environment. E-models assisted in achieving goals and objectives in PBL. Students’ better understanding of goals and objectives in PBL helped them to retain knowledge and skills for future application in clinical environment (Prosser & Sze, 2014). Results found in this study provided understanding of students’ cognitive, behavioral and motivational regulation (Nicol &
Macfarlane-Dick, 2006) to using e-models in PBL. It bridged a gap of discrepancy between expectations of the faculty and the students, thus had high value for faculty development (Steinert et al., 2006). The general increase of students’ importance ratings on goals and objectives in both self-assessment and facilitator-assessment of PBL illustrated that using e-models enhanced the students’ understanding of the faculty’s expectations in PBL tutorials. It also implied that implementation of e-models had good compatibility with PBL and was consistent with PBL teaching strategies.

Extra computational skills were required in order to use e-models to do measurement, analysis and design, which meant that the students needed to practice using e-models as a part of their preparation for PBL tutorials. Therefore the students were more aware of the learning objective “Complete assigned tasks on time”. Besides computational skills, communicational skills were also important training objectives in dental education (Hannah, Millichamp, & Ayers, 2004). Students’ were trained in active listening rather than passive listening as they changed from traditional lectures to PBL tutorials. Active listening (Rogers & Farson, 1979) required full attention to the content of the conversation in order to obtain information, show appreciation and empathise with the speaker. Active listening skills affected not only PBL learning efficiency, but also future communication with others, especially patients in clinical settings. The statistically significant result of the objective “Active listener” demonstrated that using e-models created positive influence in the process of information obtaining and knowledge exchange.

Small group teaching was one of the essential elements of PBL. Facilitators played an important role in guiding discussions and facilitating proper group functions. Facilitators helped to introduce problems and to guide the students through problem-solving process, instead of giving answers directly. Students’ critical thinking ability and self-evaluation ability were main focuses of this teaching method. The students found e-models helpful in achieving these goals, shown by statistical significance found in t-test results of five questions, i.e. “Promote group problem solving”, “Promote appropriate group function”, “Facilitate your learning”, “Promote your critical thinking” and “Promote your learning”. Although general result of the other two questions were statistically non-significant, majority of subquestions in these two sections showed significance in t-test, see Fig. 4. The results confirmed that e-models enhanced the students’ understanding of the facilitator’s role in developing their critical thinking ability as well as self-evaluation ability from constructing the group problem solving learning environment.

While solid plaster casts had limited amount of usage, online learning system allowed the students to download study e-models for their PBL preparation outside tutorial rooms. Therefore the student’s PBL preparation was strongly encouraged, which was reflected as significant increase of time spent on PBL preparation, both total time and online study time. This correlation between the students’ attention and their PBL preparation time can be useful in future curriculum design. For example different forms of learning resources could be provided to attract the students’ attention. Prolonged online PBL preparation time was found positively correlated to the students’ perceived importance of study purposes, such as “Apply knowledge to the problem”, “Able to contribute new information”, “Willing to question” and “Critical assess data”, under the categories of “Well in reasoning” and “Communication well”. One possible explanation was that study e-models provided more detailed information as well as better treatment outcome simulation than traditional plaster casts. Therefore, with a better knowledge of e-models, the students might find their thinking and discussion process more interesting and productive. On the other hand, linear correlation was found between the facilitator-
assessment object “Ask you to evaluate the quality of learning resources used” and increase in the students’ time on internet for PBL preparation. It echoes with the calling to improve the quality of e-models (Bell, Ayoub, & Siebert, 2003) for their further application in PBL or in other courses.

The theme extraction function of “Leximancer” provided a systematic and practical way to understand the students’ perceptions of using e-models from the huge text content of their feedbacks in the questionnaires. The first theme “Comparing with solid plaster casts” illustrated e-model’s advantage in long-term maintenance and storage, as well as the concern of additional hardware support such as monitors for e-models. The perception “It is better to have the use of both e-models and plaster casts” implied that the students may need more time to get used to e-models in PBL. The second theme “The use in lab stages” had an overlapping area with the first theme, which corresponded to the conceptual similarity between these two themes about the concern of additional requirements needed for implementation of e-models. The concern in the second theme was focused on extra skills required for image scanning and using software in lab stages. Furthermore, the concept word “communication” linked the second theme and the third theme “Patient feeling”. Communication between dentists and co-workers such as lab technicians, other dentists and patients was enhanced by e-model’s advantages such as easy transportation and detailed presentation. The students’ feedback about their needs of extra skills and more informative communication was consistent with statistical significance found in perceived importance of objects “Complete assigned tasks on time” and “Active listener”. The fourth theme “computational support” and the fifth theme “Cost” focused on requirement and cost to set-up and maintain e-model system, including both hard- and software. Since the students’ feedbacks in these two themes were mainly concerned about establishment of e-model system rather than long-term usage, little conceptual similarity was found between these two themes and the first three themes.

The sixth theme “Treatment planning” was the students’ feedback about e-model’s function in treatment planning. Functions such as undo, soft copy and simulation were considered beneficial in the process of treatment planning, helping the students to compare different treatment options, make diagnostic wax-up and analyse occlusal movement during treatment. E-models made it possible to visualize both treatment process and treatment outcomes, and pin point function allowed the students to give more accurate instructions as they communicated with co-workers. Meanwhile, some students thought that there were no virtual articulator function in e-model software, probably because it was not introduced by the facilitators in PBL tutorials. It proved that the students’ knowledge of e-models heavily relied on facilitators’ demonstration in PBL tutorials. Combining this with the statistical results, we can see why e-models made the facilitator’s role stronger in PBL tutorials. In addition, e-models provided a method to study and prepare for PBL with higher accuracy, which agreed with the positive correlation found between PBL preparation time and the students’ reasoning and communication abilities. The seventh theme “Preparation of models” showed that e-models were considered to be both convenient and environmental-friendly. Together with 3D printing technology, e-models may have potentiality of mass production as well (Yau, Yang, & Lin, 2016). The last theme “Quality of models” illustrated the students’ concern about accuracy of details in e-models. It agreed with the correlation found between the students’ perception of the facilitators-evaluation question “Ask you to evaluate the quality of learning resources used” and their time on internet for PBL preparation. The curriculum designers hence should keep on monitoring the quality of e-models, especially the accuracy of information provided by e-models.
Understanding of expectation from both the dental faculty and the students allowed curriculum designers to design and modify PBL curriculum to achieve better teaching outcome and reduce facilitators’ workload. Faculty support was critical for continuous improvement of facilitators (McLean, 2003), especially when innovative technologies such as e-models were first introduced into the curriculum. Since not all facilitators were experts in using e-models, they might have difficulties in demonstrating e-model functions or finding the right time to use e-models in PBL. Facilitator training was therefore necessary to improve their skills in using e-models, so as to smoothen the process of implementing e-models into original PBL setting, and enhance the students’ understanding of PBL principles (Chung, Hitchcock, Oh, Han, & Woo, 2011). Facilitators’ performance in PBL tutorials could be a role-model for the students to understand, experience and adapt to PBL learning (Hmelo-Silver & Barrows, 2006). Findings from this study suggested that facilitator training should emphasize more on their skills of using e-models in problem analysis, treatment planning and giving instructions, so that the students could benefit more from informative communication, critical thinking and group problem solving process. Furthermore, the study results also suggested a demand for stronger technology support including high-quality e-models and computational skill tutorials for the students.

5. Limitation

Interpretation of the results should be with caution. Discussion of the implications of quantitative results might be enhanced by addressing some issues. For example, it seemed like some the changes in students’ understanding might be attributed to other aspects of PBL experiences, instead of e-models usage solely. Small sample size of the study limited validity of statistical significances of the results. Comparison groups used in t-tests were two data sets of the students’ perception before and after using e-models in PBL. Further statistical tests should be run for different comparison groups according to the students’ characteristics (Das, Mpofu, Hasan, & Stewart, 2002). Besides, analyses of this study based on measurement of the students’ perception changes to PBL. It restricted generalization of the study results in teaching environments other than PBL. Also, facilitators’ viewpoints were not included in this study. A further study of the facilitators’ perception could provide a more dynamic picture of using e-models in PBL. Moreover, only impacts of using e-models in PBL settings were analyzed in this study. Impacts of PBL to the students’ skills in using e-models were not studied, which could be one direction for future study design. Follow-up measurement of the students’ performance can further evaluate their learning outcomes and analyse its relationship with the students’ perception of teaching purposes.

5. Conclusion

The students’ higher importance ratings on all goals and objectives in current student self-assessment and facilitator assessment of PBL showed an increased understanding of the faculty’s expectation in blended PBL with the help of e-models. It illustrated compatibility between implementation of e-models and expectation of PBL. Qualitative analysis of open-ended questions was done with visual text analytic software Leximancer to extract themes from contents of the students’ feedbacks and results were found to improve validity of statistical results. Extra skill needs required to use e-models and new informative communication made possible by e-models explained significant changes of the students’ importance ratings on objectives “Complete assigned tasks on time” and
“Active listener” in self-assessment. Besides, e-model functions in treatment planning, problem analysis and giving instructions supported significant changes of the students’ importance ratings on facilitators’ role in training critical thinking and guiding group problem-solving. Meanwhile, regression analysis was used to find correlation between the students’ awareness of teaching objectives and their behavior in PBL preparation. The students’ attention to objectives under self-assessment categories “Well in reasoning” and “Communication well”, as well as to facilitator assessment objective “Ask you to evaluate the quality of learning resources used” were found to be associated with their increase in PBL preparation time on the Internet. It provided insights that e-model online learning resources could influence the students’ behavior in PBL preparation and assist the students’ to understand and analyze problems. Trainings for facilitators’ to enhance their skills in using e-models and integrating those skills into facilitation in PBL was hence critical for continuous development of this innovative method. Stronger support from the faculty such as high quality e-models and video tutorials to the students for related computational skills should also be available to cope with the students’ needs in their PBL preparation.

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References


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

Hai Ming Wong, Kuen Wai Ma, Lavender Yu Xin Yang, Yanqi Yang

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
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)](image-url)
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

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item description</th>
<th>Before</th>
<th>After</th>
<th>Change in means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Use of multiple sources of learning</em></td>
<td>Mean (SD)</td>
<td>Mean(SD)</td>
<td>Mean(SD)</td>
</tr>
<tr>
<td>A1**</td>
<td>I am ready to learn without the help of traditional lecture</td>
<td>8.36(1.33)</td>
<td>9.06(1.19)</td>
<td>+ 0.70</td>
</tr>
<tr>
<td>A2**</td>
<td>I am ready to learn with the help of tutor feedback</td>
<td>8.14(1.77)</td>
<td>7.18(1.84)</td>
<td>- 0.96</td>
</tr>
<tr>
<td>A3</td>
<td>I am ready to acquire information through internet search</td>
<td>7.02(1.72)</td>
<td>7.44(1.60)</td>
<td>+ 0.42</td>
</tr>
<tr>
<td>A4*</td>
<td>I am ready to acquire information by reaching out to others</td>
<td>7.55(1.60)</td>
<td>6.97(1.60)</td>
<td>- 0.58</td>
</tr>
<tr>
<td>A5</td>
<td>I am ready to learn through my own observation</td>
<td>6.97(1.56)</td>
<td>7.14(1.73)</td>
<td>+ 0.17</td>
</tr>
<tr>
<td>A6</td>
<td>I am ready to learn experience</td>
<td>7.67(1.74)</td>
<td>7.75(1.40)</td>
<td>+ 0.08</td>
</tr>
<tr>
<td>A7</td>
<td>I can use my personal experience to facilitate new learning</td>
<td>7.25(1.94)</td>
<td>7.68(1.22)</td>
<td>+ 0.43</td>
</tr>
<tr>
<td>A8</td>
<td>I can use what I learned from other courses to facilitate new learning</td>
<td>6.89(1.66)</td>
<td>7.02(1.89)</td>
<td>+ 0.13</td>
</tr>
<tr>
<td></td>
<td><em>Readiness for self-directed learning</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A9</td>
<td>Freedom in deciding what I am going to learn fits better with my learning needs</td>
<td>6.24(1.67)</td>
<td>6.67(1.95)</td>
<td>+ 0.43</td>
</tr>
<tr>
<td>A10</td>
<td>Getting to know an area through my own exploration is satisfying</td>
<td>6.67(1.51)</td>
<td>6.73(1.55)</td>
<td>+ 0.06</td>
</tr>
<tr>
<td>A11</td>
<td>I talk initiative to assess my learning needs and formulate my learning goals</td>
<td>6.73(1.65)</td>
<td>6.79(1.25)</td>
<td>+ 0.06</td>
</tr>
<tr>
<td>A12</td>
<td>When I run into a problem, I am ready to look for relevant resources</td>
<td>7.10(1.12)</td>
<td>7.18(1.45)</td>
<td>+ 0.02</td>
</tr>
<tr>
<td>A13</td>
<td>I am ready to evaluate the information I get</td>
<td>6.71(1.36)</td>
<td>6.95(1.32)</td>
<td>+ 0.24</td>
</tr>
<tr>
<td>A14</td>
<td>I am ready to apply knowledge to new problem situation</td>
<td>6.63(1.46)</td>
<td>6.79(1.41)</td>
<td>+ 0.14</td>
</tr>
<tr>
<td></td>
<td><em>Readiness for group/peer learning</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A15</td>
<td>Exchange of information and opinion in group provides good stimulation</td>
<td>7.36(1.36)</td>
<td>7.42(1.62)</td>
<td>+ 0.06</td>
</tr>
<tr>
<td>A16</td>
<td>We can learn faster with more people sharing the learning tasks</td>
<td>6.91(1.94)</td>
<td>6.95(1.90)</td>
<td>+ 0.04</td>
</tr>
<tr>
<td>A17</td>
<td>I would prepare relevant information for group sharing</td>
<td>7.04(1.27)</td>
<td>7.38(1.60)</td>
<td>+ 0.34</td>
</tr>
<tr>
<td>A18</td>
<td>I know how to contribute in group learning situation</td>
<td>6.91(1.49)</td>
<td>7.08(1.53)</td>
<td>+ 0.17</td>
</tr>
<tr>
<td>A19</td>
<td>Discussion with others would enhance my understanding of the subject</td>
<td>7.31(1.53)</td>
<td>7.51(1.67)</td>
<td>+ 0.20</td>
</tr>
<tr>
<td>A20</td>
<td>Group emotional support would enhance my learning motivation</td>
<td>7.14(2.06)</td>
<td>6.71(1.47)</td>
<td>- 0.43</td>
</tr>
<tr>
<td>A21</td>
<td>I am ready to lead discussion</td>
<td>6.00(1.83)</td>
<td>6.34(1.86)</td>
<td>+ 0.34</td>
</tr>
<tr>
<td>A22</td>
<td>I think group conflict is best handled by the member themselves</td>
<td>6.85(1.77)</td>
<td>6.83(1.46)</td>
<td>- 0.02</td>
</tr>
<tr>
<td></td>
<td>Team work in project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A23</td>
<td>I am ready to explore conflicting ideas</td>
<td>6.75(1.61)</td>
<td>6.73(1.31)</td>
<td>- 0.02</td>
</tr>
<tr>
<td>A24</td>
<td>I am able to accept and respond to feedback/criticism gracefully</td>
<td>7.30(1.66)</td>
<td>7.42(1.42)</td>
<td>+ 0.12</td>
</tr>
<tr>
<td>A25</td>
<td>I am ready to give feedback to others</td>
<td>6.59(1.73)</td>
<td>6.55(1.64)</td>
<td>- 0.04</td>
</tr>
<tr>
<td>A26*</td>
<td>I could recognize the strengths and weakness of each in a group learning process</td>
<td>6.28(1.33)</td>
<td>6.81(1.39)</td>
<td>+ 0.53</td>
</tr>
<tr>
<td>A27</td>
<td>I am ready to compromise with others to come to joint decision</td>
<td>7.10(1.46)</td>
<td>6.86(1.19)</td>
<td>- 0.24</td>
</tr>
<tr>
<td>A28</td>
<td>I am punctual</td>
<td>7.67(2.10)</td>
<td>7.83(1.62)</td>
<td>+ 0.16</td>
</tr>
<tr>
<td>A29</td>
<td>I am ready to change my perception of the problem with new information brought in</td>
<td>7.18(1.28)</td>
<td>7.28(1.36)</td>
<td>+ 0.10</td>
</tr>
<tr>
<td>A30</td>
<td>I am ready to contribute my best in a team project</td>
<td>7.10(1.41)</td>
<td>7.24(1.42)</td>
<td>+ 0.14</td>
</tr>
</tbody>
</table>

* 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

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

* 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

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

The authors have no conflict of interest.

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REFERENCES


Title: 3D E-models for learning in Dentistry – a qualitative study

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Key words: 3D E-models, dental education and qualitative study

Objective: To explore dental students’ attitudes towards learning through 3D E-models in Dentistry in Hong Kong.

Method: Six focus groups (28 males and 26 females, 9 students in each group) were conducted in Faculty of Dentistry, The University of Hong Kong after 1 months’ learning experience with 3D E-models in Problem Based Learning and Case Based Learning. Eligible participants were year IV dental students, who were involved in a teaching development programme. The face-to-face semi-structured interviews (30-45 minutes each) were audio-recorded. Initial guiding questions were on the students’ perceptions towards the advantages and disadvantages of 3D E-models, motivation and experience of various learning processes, and learning effectiveness. Qualitative data collected were analyzed using a thematic approach including transcript coding, data display and interpretation.

Result: Advantages of 3D E-models reported by the students included easy demonstration and transferal to colleagues, parents and patients; simpler measurement, comparison and storage; and reduced risk of misplacement, disappearance and damage. Disadvantages were the lack of requisite fine “feel” for clinical techniques, and limited functions provided by the available software developed for dental use. Almost all students referred to the 3D E-model as a user-friendly and interesting tool that would help to motivate their learning and discussion. The trend of modern dentistry moving towards “electronic patient records” for clinical treatment, and young people’s familiarity with virtual modalities were frequently mentioned expositions. Nearly half
of the students were aware of their improvement through learning with 3D E-models. However, most of the students preferred to use 3D E-models and plaster casts at the same time.

Conclusion: The dental students’ motivation was positively associated with the innovation of 3D E-models. However, learning effectiveness could not be directly related to the application of 3D E-models. (The work described in this abstract was fully supported by a Teaching Development Grant, The University of Hong Kong.)
Objective:
To explore dental students’ attitudes towards learning through 3D E-models in Dentistry in Hong Kong.

Method:

- 54 BDS V students from Faculty of Dentistry in The University of Hong Kong involved in a teaching development programme
- 1 month 3D E-models learning experience
- Problem Based Learning + Case Based Learning
- Face-to-face semi-structured interviews were audio-recorded
- Transcript coding
- Data display
- Data interpretation

Students’ perceptions of 3D E-models
- Advantages
  - Motivation
  - Learning effectiveness
- Disadvantages
  - Experience

Results:
- Nearly half of the students were aware of their improvement through learning with 3D E-models.
- Most of the students preferred to use 3D E-models and plaster casts at the same time.

Advantages
- Simpler measurement (Fig. 1), comparison and storage.
- Easy demonstration (Fig.2) and transferal to others.
- Reduced risk of misplacement, disappearance and damage.
- User-friendly.
- Interesting tool.
- Motivate students’ learning and discussion.
- The trend of modern dentistry moving towards “electronic patient records” for clinical treatment.
- Young people’s familiarity with virtual modalities.

Disadvantages
- Lack of requisite fine “feel” for clinical techniques.
- Limited functions provided by the available software developed for dental use.

Conclusion:
- Motivation was positively associated with the innovation of 3D E-models.
- Learning effectiveness could not be directly related to the application of 3D E-models.

Key words:
3D E-models, dental education and qualitative study

Acknowledgement:
The work described in this abstract was fully supported by a Teaching Development Grant, The University of Hong Kong.

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Learning in Paediatric Dentistry – 3D E-models vs. plaster casts
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BACKGROUND
Three-dimensional technology is in extensive application in education of various disciplines. The Faculty of Dentistry of The University of Hong Kong has been developing 3D E-models as one of the innovative resources for clinical teaching. The vision is to support interactive learning and to abreast the electronic-record era in modern Dentistry. The work described in this abstract was fully supported by a Teaching Development Grant, The University of Hong Kong.

AIM
To compare dental students’ attitudes towards learning in Paediatric Dentistry through 3D E-models and plaster casts in Hong Kong.

DESIGN
A qualitative study design was adopted. Four focus groups (18 BDS IV students and 18 BDS V students; 20 males and 16 females; 9 students in each group) were conducted after learning "Dento-alveolar growth in 12, 15 and 18 years old adolescents" with 3D E-models and plaster casts. Initial guiding questions were on the students’ motivation and learning effectiveness towards these two methods. Students’ feedback was audio-recorded. Qualitative data collected were coded, displayed and interpreted.

RESULTS
Most students perceived that the 3D E-model could motivate their learning because it was more interesting than the plaster cast. The measurements on 3D E-models were also easy to perform. Almost all students referred to the 3D E-model as a more useful tool to learn the growth in adolescents especially when the function of "superimposition" was applied.

CONCLUSION
The majority of the students perceived more increase in motivation and learning effectiveness in Paediatric Dentistry using 3D E-models.

ACKNOWLEDGEMENT
This study was supported by the Teaching Development Grants, The University of Hong Kong.
Learning in Paediatric Dentistry – 3D E-models vs. plaster casts

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Aim
To compare dental students’ attitudes towards learning in Paediatric Dentistry through 3D E-models and plaster casts in Hong Kong.

Background
Three-dimensional (3D) technology is in extensive application in education of various disciplines. The Faculty of Dentistry of The University of Hong Kong has been developing 3D E-models as one of the innovative resources for clinical teaching. The vision is to support interactive learning and to abreast the electronic-record era in modern Dentistry.

Methods
A Qualitative Study

18 BDS IV + 16 BDS V students

Group I
Group II
Group III
Group IV

16 patients

Learning “Dento-alveolar growth in 12, 15 and 18 years old adolescents”

3D E-models
plaster casts

Questions about

- Students’ motivation
- Learning effectiveness

Students’ feedback

Audio records

Qualitative data

- Coded
- Displayed
- Interpreted

Figure 1. “Superimposition” of E-models before-treatment (grey) and after-treatment (blue)

Results

Students’ Perception

More interesting

Easier measurements of dimensions

Additional function of “superimposition”

Higher Motivation

in learning of the growth in adolescents

More useful tool

Figure 2. Arbitrary rotation and translation of 3D E-models on user interface

Conclusion
The majority of the students perceived more increase in motivation and learning effectiveness in Paediatric Dentistry using 3D E-models.

Acknowledgement
This study was supported by the Teaching Development Grants, The University of Hong Kong.