A multimedia CD-ROM tool to improve student understanding of bile salts and bilirubin metabolism: evaluation of its use in a medical hybrid PBL course

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Received 21 June 2004; accepted in final form 29 November 2004

Azer, Samy A. A multimedia CD-ROM tool to improve student understanding of bile salts and bilirubin metabolism: evaluation of its use in a medical hybrid PBL course. Adv Physiol Educ 29: 40–50, 2005; doi:10.1152/advan.00015.2004.—Over the last 35 years our understanding of bile salts, bilirubin metabolism, and hepatobiliary transport has progressively increased. From 1965 to the end of 2002, 3,610 articles and review papers have been published on hepatobiliary and enterocyte transport of bile salts. However, there is a lack of information in the content of current textbooks about hepatobiliary physiology, bile salt transporters, bile formation, mechanisms underlying cholestasis, and drug-induced liver injury. The use of an integrated multimedia program on the liver covering these gaps in textbooks may be useful to student learning. This study aims to 1) assess student views on a multimedia CD-ROM (“The Liver”) integrating basic and clinical sciences related to the liver, bile salts, and bilirubin metabolism, 2) assess the usefulness of problem-based learning (PBL) cases included in the multimedia CD-ROM, and 3) assess student learning before and after use of the multimedia CD-ROM. A total of 106 first-year medical students (27 with and 79 without a prior university degree) at the University of Melbourne participated in this study. Students were tested on the liver, bile salts, and bilirubin metabolism before and after using the multimedia CD-ROM. After completing the multimedia CD-ROM, each student filled out a 5-point Likert scale questionnaire evaluating the features of the program and its usefulness to their learning. Results show that the aims of the package were clear to participants, the contents were logically organized and clear, the key concepts were easy to identify, the contents were pitched to an appropriate level, and the package was interactive and encouraged participants to reflect on their learning. Students also agreed that the assessment tools used in the program and the feedback provided were meaningful and helpful to their learning. No differences were found when responses were compared on the basis of academic background, gender, citizenship, or first language of participants. Students agreed that the PBL cases in the CD-ROM kept them engaged, were useful to their learning, and matched with the overall philosophy of the program. Compared with graduate-entry students (those with a prior university degree), school leavers (those with no prior university degree) showed a more positive attitude toward the PBL cases included in the multimedia CD-ROM and agreed that cases kept them engaged (P = 0.033). Students who completed the test after using the multimedia CD-ROM scored higher compared with those who completed the test before using the multimedia CD-ROM (P <0.001). In conclusion, using bile salts, bilirubin metabolism, and their hepatobiliary transport as an example, the incorporation of a multimedia CD-ROM into the first-year medical course has the potential to improve student understanding of the main concepts in a variety of body systems.

medical education; basic sciences; problem-based learning; the liver transporters

INTRODUCTION OF PROBLEM-BASED learning (PBL) in a medical curriculum has resulted in the integration of basic and clinical sciences, encouragement of self-directed learning, and changing of the focus from "rote" learning to understanding concepts (1, 3, 31). Students in a PBL course use a wide range of resources including journal articles, educational websites, practical classes, multimedia CD-ROMs, and textbooks. A number of research studies (19, 20, 28, 37, 41, 48) have demonstrated a number of limitations of undergraduate medical textbooks, and, more recently, it has been shown (5) that there is an imbalance in the contents of current textbooks and a lack of information about hepatobiliary physiology, bile salt transporters, bile formation, and mechanisms underlying cholestasis and drug-induced hepatobiliary dysfunction.

Multimedia CD-ROMs and computer-aided programs have been widely used in PBL curricula (16, 23, 29, 30, 32–34, 44, 49). These tools provide a valuable resource to help students evaluate their learning, explore main concepts related to the problem of the week, and deepen their understanding of the whole picture as well as the fine details. Multimedia CD-ROMs have been found useful in teaching a wide range of disciplines e.g., gross anatomy (29, 11), brachial plexus injuries (22), histology (33, 34), acid-base disorders (35, 38), nutrition (36), cardiac auscultation (21, 44), electrocardiography (17), diagnosis of anemia and coronary artery disease (32), urology (47), parasitology (50), radiology (27), geriatric medicine (2), ophthalmology (16), dental sciences (40), and veterinary education (25). These studies have documented that multimedia CD-ROM and web-based learning tools are as effective as other methods of teaching and can be used as an adjunct to traditional education (40), act as a stimulus for further learning (16) and are a useful supplement to traditional teaching of geriatric medicine (2). Other studies found that these tools may provide a more effective means of evaluating the learner’s mastering of a topic (24) and have reduced the time spent by students in a histology laboratory (33).

However, there is no mention in the literature of studies evaluating a multimedia CD-ROM addressing the liver or hepatobiliary system. Furthermore, most multimedia CD-ROMs used by medical students are discipline-based rather than addressing integration of knowledge across disciplines such as anatomy, histology, physiology, biochemistry, pharmacology, and cell biology. They also do not reflect on the philosophy of PBL and do not address the use of basic sciences in clinical situations.

Why Is It Important To Integrate Basic and Clinical Sciences in a Multimedia CD-ROM?

Integration between basic sciences and clinical medicine has been found to stimulate profound rather than superficial learn-
ing, thereby stimulating student understanding of important biomedical principles. It has also been proposed that integration has the potential to enhance retention of knowledge and the ability of students to apply knowledge in real-life situations (13). The educational outcomes of integration of basic sciences and clinical sciences in a multimedia CD-ROM has been discussed in the literature (7, 46). It is believed that integration will allow students to

- realize the significance of information learned from basic sciences such as physiology, anatomy, biochemistry, pharmacology, and pathology in clinical situations (46),
- understand the scientific basis behind patients’ presenting symptoms and elicited physical signs,
- use knowledge learned from biological sciences to build mechanisms and understand the pathogenesis of different disorders,
- discover the relationship between biological sciences and their clinical applications (46),
  
  - enhance student skills in reasoning, justification, and interpretation of laboratory findings, and
  - retrieve what they learned when they encounter similar circumstances in clinical practice.

What Are the Educational Values of Using PBL Cases in a Multimedia CD-ROM?

Although many students cope admirably with the didactic teaching (e.g., lectures and seminars) and follow up their learning using textbooks or other resources, there are students for whom the addition of alternative methods of learning/teaching enhances their knowledge base and understanding of the relevant material. Learners differ in choosing the best method of instruction for their learning. However, there is current evidence that students comprehend an issue by doing tasks and actively engaging in solving a problem (1, 3, 12, 18). The use of PBL cases in a multimedia CD-ROM will allow

Table 1. Summarises the problem-based learning (PBL) cases and main concepts raised in the curriculum including lectures and practical classes at the University of Melbourne during weeks 9–11 (hepatobiliary system weeks).

<table>
<thead>
<tr>
<th>Week</th>
<th>PBL Case Covered in Curriculum</th>
<th>Main Issues/Concepts Raised in Lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 9</td>
<td>Breast milk jaundice in a full-term newborn</td>
<td>Liver structure and function</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use of liver enzymes in liver disorders and other diseases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bilirubin metabolism and liver dysfunction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alcohol and liver</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cells of the liver and their function</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patterns of liver injury</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drug metabolism and excretion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pharmacodynamics and pharmacokinetics principles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drug interactions</td>
</tr>
<tr>
<td>Week 10</td>
<td>Liver cirrhosis</td>
<td></td>
</tr>
<tr>
<td>Week 11</td>
<td>A patient with epilepsy and drug interaction (role of the liver in drug metabolism)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Study profile. Participants volunteered in the MCQs test in weeks 9, 10, and 11.
students to develop a number of learning skills (14, 15, 26, 32, 38) including

- hypotheses generation for each problem identified in the trigger,
- building mechanisms to explain their hypotheses,
- collection of new information via medical history and clinical examination,
- ranking their hypotheses on the basis of the new information and clinical findings,
- understanding the scientific basis behind patient symptoms and clinical findings,
- interpretation of laboratory findings,
- weighing evidence for and against each hypothesis,
- making decisions,
- reflection on psychosocial, ethical, and moral issues in the case, and
- outlining the management plan, management options, and factors that may affect the management plan.

The aims of this study were 1) to assess student views on a multimedia CD-ROM integrating basic and clinical sciences related to the liver, bile salts, bilirubin metabolism, and hepatobiliary transport; 2) to assess the usefulness of PBL cases included in the CD-ROM; and 3) to assess student learning before and after using the multimedia CD-ROM.

The aims of this study were 1) to assess student views on a multimedia CD-ROM integrating basic and clinical sciences related to the liver, bile salts, bilirubin metabolism, and hepatobiliary transport; 2) to assess the usefulness of PBL cases included in the CD-ROM; and 3) to assess student learning before and after using the multimedia CD-ROM.

### Table 2. Summary of educational objectives and interactive tasks in each module in the multimedia CD-ROM, titled “The Liver: Understanding Bile Salts and Bilirubin Metabolism: An Interactive Computer Program Integrating Basic and Clinical Sciences”

<table>
<thead>
<tr>
<th>Module</th>
<th>Educational Objectives</th>
<th>Interactive Tasks Included in the Multimedia CD-ROM</th>
</tr>
</thead>
</table>
| Module 1: Interactive PBL cases  | *Case 1*: Abdominal pain/gallstones.  
*Case 2*: Drug-induced liver dysfunction  
*Case 3*: Jaundice in a pregnant refugee patient | *Generate hypotheses*  
*Build mechanisms for their hypotheses*  
*Refine hypotheses on basis of available evidence*  
*Seek new information from history or clinical examination*  
*Interpret laboratory findings*  
*Plan management strategies* |
| Module 2: The functions and structure of liver cells | Understand the structure and function of the liver at body system, organ, cellular, and molecular levels | *Build a liver model*  
*Drag and drop exercise*  
*Build flow charts*  
*Observe the direction of bile and blood flow in a liver model*  
*Move transporters to the sinusoidal and canalicular domains of a hepatocyte and test their functions*  
*Work out quizzes and answer MCQs and scenario based questions* |
| Module 3: Bilirubin metabolism and liver function tests | Understand the metabolism of bilirubin, the pathogenesis of jaundice, and the scientific basis and uses of bilirubin and liver enzyme blood levels in hepatobiliary disorders | *Build liver models*  
*Label chemical structures*  
*Build flow charts*  
*Move transporters to their appropriate site and test their functions*  
*Work out quizzes and answer MCQs and scenario based questions* |
| Module 4: Bile salts and enterohepatic circulation | Understand recent developments in the transport of bile salts and the enterohepatic circulation in health and disease | *Build liver models*  
*Build flow charts*  
*Realize how differences in chemical structure of bile salts affect their solubility and function*  
*Move transporters to their appropriate site and test their functions*  
*Construct an enterohepatic circulation model*  
*Observe consequences of pathological processes on the enterohepatic circulation*  
*Work out quizzes and answer MCQs and scenario based questions* |

MCQs, multiple choice questions.
completed survey you are giving permission to the investigator to use the data in a research project.”

Study design. Early in week 9 and before working on the multimedia CD-ROM, students completed a test comprising 23 MCQs (control group, \( n = 27 \)). During week 10, another group of students, after attending six lectures addressing issues related to the liver, completing the breast milk jaundice PBL case in their groups, attending Tutorial 1 of a PBL case on liver cirrhosis, and after working on the multimedia CD-ROM, answered the same test questions used in the control group (group 1, \( n = 18 \)) (Fig. 1). During week 11, after completing two PBL cases and Tutorial 1 of a PBL case covering the role of the liver in drug metabolism and before working on the multimedia CD-ROM, a third group of students completed the same test used in the control group (group 2, \( n = 21 \)). At the end of the last session in week 11, the same group of students answered the same test questions (group 3, \( n = 21 \)). The questions used in all tests were identical, and their contents reflected the educational objectives of the multimedia CD-ROM and the medical course. The introduction of the multimedia CD-ROM in these weeks aimed at enhancing self-directed learning and a deep understanding of difficult concepts. It also provided students with the opportunity to apply knowledge learned in clinical situations and restructure knowledge learned from other resources according to their needs. These approaches aimed at enhancing student understanding and mastering of main concepts related to the liver and hepatobiliary system. It also helped in their formative assessment via the feedback provided in PBL cases and the tasks included in the multimedia CD-ROM.

Software package. Development of the multimedia CD-ROM was undertaken in ~3 yr from February 2000 to December 2002 and was evaluated during September 2002. The preparation of these modules was a demanding task aimed at creating an innovative and creative package that encourages self-directed learning. “The Liver” CD-ROM (6) comprises four main modules (see Table 2). The interactive activities in the multimedia CD-ROM have been designed by using a particular media component and an interface that best enhances the engagement of users, facilitation of integration of knowledge, and enforcement of the educational principles discussed. Table 2 summarizes the educational objectives and interactive tasks in each module in the multimedia CD-ROM. The pedagogical model underlying “The Liver” CD-ROM highlights the educational philosophy of PBL. The CD-ROM comprises a number of interactive tasks, which enhances deep understanding of concepts, application of knowledge, engagement in the learning process, weighing evidence for each hypothesis, and ability to critically analyze information and make reasonable decisions. Table 3 summarizes examples of the interactive activities used in “The Liver” CD-ROM. The CD-ROM also encourages students to identify problems, generate hypotheses, collect new information, build mechanisms, construct a three-dimensional liver model, assess consequences of pathophysiological changes, identify factors contributing to a problem, interpret laboratory findings, and design a management plan. Figure 2 summarizes the multistage educational process and feedback designed in the template of the PBL cases. Figures 3 and 4 show examples of two screens from “The Liver” CD-ROM.

**Table 3. Examples of interactive activities used in “The Liver” CD-ROM**

<table>
<thead>
<tr>
<th>Interactive Activity</th>
<th>What Do Students Need to Do?</th>
<th>Educational Objectives</th>
</tr>
</thead>
</table>
| Build a liver model | ● Students read brief information about each structure in the animation  
● Students construct a liver sinusoid using endothelial cells, Kupffer cells, neurokinin cells, red blood cells, and stellate cells  
● Once students have completed this portion, move on to a three-dimensional animation of liver cells (hepatocytes)  
● If student fails to place it in the correct position, it bounces back to its original place | ● Learn the anatomy and function of different cells in the liver  
● Understand which of these structures is inside or outside the endothelial sinusoid  
● Understand the relationship between different structures forming a liver  
● Three-dimensional model helps students to see relationships and better understand pathophysiological mechanisms |
| Show the correct transporters at sinusoidal and canalicular membranes of a liver cell | ● Students read a brief summary about each transporter  
● Students drag and drop appropriate transporters to the sinusoidal or canalicular domains of a liver cell (hepatocyte) animation  
● If a transporter is moved to the wrong place, the transporter bounces back to its original place | ● Difference between transporters at sinusoidal and canalicular domains  
● Undergraduate the function of each transporter  
● Understand the processes by which bilirubin and bile salts are taken up by liver cells (hepatocytes)  
● Understand the enterohepatic circulation of bile salts and bilirubin  
● Understand the different mechanisms by which jaundice occurs |
| Provide reasoning | ● Type evidence for and against each hypothesis student has  
● Weigh the evidence for each hypothesis and refine student’s final hypothesis | ● Understand the importance of collecting information using history, clinical examination, and laboratory tests  
● Practice interpretation of findings and their significance  
● Practice the scientific approach in decision making |
| Build mechanisms for student’s hypothesis | ● Design a flow diagram that summarizes the pathogenesis of student’s hypothesis | ● Realize the significance of information provided in history in constructing a mechanism  
● Learn how to integrate information from physiology, pathology, biochemistry, and microbiology as student builds mechanism  
● Discover gaps in knowledge and need to search for information to complete mechanism |
or from overseas, and their native language. Questions addressing objectives, directions, contents, and structure of “The Liver” modules (questions 9–15) were designed to assess student evaluation of the modules, particularly with respect to the clarity of the objectives of each module, the contents and key concepts, flow and sequence of information, and the amount of information on each screen (43). To further assess these issues, an open-ended statement “Feel free to add any other comments” was included.

The third section of the survey (questions 16–22) was designed to assess the degree of interactivity in these modules, navigation, function of buttons and links, use of color, the quality of graphics, and their use in relation to topics. The fourth section (questions 23–25) was designed to assess student evaluation of the PBL cases included in module 1, particularly whether they matched with the PBL in the curriculum and whether the cases kept them engaged and were useful to their learning. The last section (questions 26) aimed at evaluation of the overall views of students about the whole package. The following open-ended statements were mentioned, “I believe that the best aspects of this package are . . . .” “I believe that this package can be improved by considering the following suggestions,” and “My other comments are . . . .” The questionnaire used in this study was piloted in 2001 before its use in 2002.

Statistical analysis. Statistical analysis was done by using the Statistical Package for the Social Sciences (42). For the test questions, one mark was allocated for each correct answer and no mark was given for an incorrect answer. The means ± SD of the test results for each group were calculated, and differences among the means of these groups were determined by using ANOVA. Regarding the questionnaire, groups were compared on the basis of demographic variables, including academic background, citizenship, and first-language using Mann-Whitney’s U-test, Wilcoxon’s signed ranks and the calculation of the $\chi^2$ value (8, 9, 10). A $P$ value of $<0.05$ was considered significant.

RESULTS

Subjects. One hundred six first-year medical students [27 (25%) with and [79 (75%)] without a prior university degree participated in this study. The majority of the participants were local students [67 (63%)] and the remaining [39 (37%)] were overseas students. Fifty nine (56%) of the participants identified English as their first language, whereas 47 (44%) respondents first spoke a language other than English.

Results of the test. Table 4 summarizes the test results for the control group and the three groups that used the multimedia CD-ROM. Compared with the control group, the mean test results of groups 1 and 3 were significantly different ($P = 0.001$ for each). Compared with group 1, the mean test results of group 2 were significantly lower ($P = 0.014$) but not when compared with those of group 3 ($P = 0.613$). The mean of the test results of group 2 were significantly lower when compared with those of group 3 ($P < 0.001$) but were not statistically significant from the control group ($P = 0.084$). The $\chi^2$ test was used.
Objectives, directions and contents of modules. Table 5 shows that participants agreed that the aims of the package were clear from the start, the contents were logically organized, and the key concepts were easy to identify. They also agreed that the flow and sequence of information from screen to screen was logical, and the content was pitched at an appropriate level. No differences were found when responses were compared on the basis of academic background, gender, citizenship, or first language of participants. School leavers, particularly those from a non-English speaking background, felt there was too much information per screen. Differences were significant from the prospective groups (Table 5). No differences were found on this issue when data were evaluated on the basis of gender and citizenship. Students commented that 2–4 screens in module 4 contained too much information.

Interactivity, navigation, use of color, and graphics. Table 6 shows that participants agreed that the package was interactive, encouraged them to reflect on educational issues related to
were not significant unless marked. A disagreement; graduate, those with prior university degree; school leavers, those with no prior university degree. Groups were studied by using the

There was too much

The flow was logical S. agree 4 (4) 17 (16) 13 (12) 8 (7.5) 13 (12) 8 (7.5) 11 (10) 10 (9.5)

It was easy to identify key

Areas discussed, and the PBL cases and feedback were meaningful. Participants also agreed that it was easy to navigate around the package with the buttons and links being easy to understand. They also agreed that the colors were well used and that graphics helped them to better understand concepts related to the liver and were of high quality and clearly related to the topic. No differences were found when responses were compared on the basis of academic background, gender, citizenship, or first language of participants.

PBL cases in the multimedia CD-ROM. Table 7 shows that participants agreed that the PBL cases kept them engaged, were useful to their learning, and matched with the overall philosophy of the program. No differences were found on the basis of citizenship or first language. Compared with graduate entrants, school leavers showed a more positive attitude toward the PBL cases and agreed that the cases kept them engaged \((P = 0.033)\). Female students compared with males, agreed that the PBL cases matched with the philosophy of the course \((P = 0.012)\) and were useful to their learning \((P = 0.048)\). The \(\chi^2\) test was used.
and completed the survey. The higher ranking of the objects, directions, contents, interactivity, use of color, graphics, and animation, has been persistently observed regardless of the academic background, gender, citizenship, or first language of participants. Comments from participants at the end of the questionnaire regarding best aspects of the package also support these notions about the features that were considered meaningful. The feedback of participants engaged (n = 57).

DISCUSSION

The present study shows strong positive feedback from first-year medical students who used the multimedia CD-ROM and completed the survey. The higher ranking of the objectives, directions, contents, interactivity, use of color, graphics, and animation, has been persistently observed regardless of the academic background, gender, citizenship, or first language of participants. Comments from participants at the end of the questionnaire regarding best aspects of the package also support these notions about the features that were considered meaningful. The feedback of participants engaged (n = 57).

**Table 6. Rating participant views regarding the interactivity, navigation, use of colour and graphics, and effects of academic background, gender, citizenship, and first language**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Academic Background</th>
<th>Gender</th>
<th>Citizenship</th>
<th>First Language</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graduate (27; 25%)</td>
<td>School Leavers, (79; 75%)</td>
<td>Females (68; 64%)</td>
<td>Males (38; 36%)</td>
</tr>
<tr>
<td>I thought the package was interactive</td>
<td>S. agree 5 (5)</td>
<td>22 (21)</td>
<td>16 (15)</td>
<td>11 (10)</td>
</tr>
<tr>
<td></td>
<td>Agree 20 (19)</td>
<td>46 (43)</td>
<td>47 (44)</td>
<td>19 (18)</td>
</tr>
<tr>
<td></td>
<td>Neutral 2 (2)</td>
<td>11 (10)</td>
<td>5 (5)</td>
<td>8 (7.5)</td>
</tr>
<tr>
<td></td>
<td>Disagree 0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td>S. Disagree 0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>The package encouraged me to reflect on educational issues related to areas discussed</td>
<td>S. agree 3 (3)</td>
<td>11 (10)</td>
<td>9 (8.5)</td>
<td>5 (5)</td>
</tr>
<tr>
<td></td>
<td>Agree 17 (16)</td>
<td>38 (36)</td>
<td>40 (38)</td>
<td>15 (14)</td>
</tr>
<tr>
<td></td>
<td>Neutral 5 (5)</td>
<td>24 (23)</td>
<td>16 (15)</td>
<td>13 (12)</td>
</tr>
<tr>
<td></td>
<td>Disagree 1 (1)</td>
<td>6 (6)</td>
<td>3 (3)</td>
<td>4 (4)</td>
</tr>
<tr>
<td></td>
<td>S. Disagree 1 (1)</td>
<td>0 (0)</td>
<td>1 (1)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>The MCQs, clinical cases, and the feedback provided were meaningful</td>
<td>S. agree 9 (8.5)</td>
<td>24 (23)</td>
<td>23 (22)</td>
<td>10 (9)</td>
</tr>
<tr>
<td></td>
<td>Agree 14 (13)</td>
<td>39 (37)</td>
<td>34 (32)</td>
<td>19 (18)</td>
</tr>
<tr>
<td></td>
<td>Neutral 2 (2)</td>
<td>13 (12)</td>
<td>8 (7.5)</td>
<td>7 (7)</td>
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<tr>
<td></td>
<td>Disagree 1 (1)</td>
<td>2 (2)</td>
<td>2 (2)</td>
<td>1 (1)</td>
</tr>
<tr>
<td></td>
<td>S. Disagree 1 (1)</td>
<td>0 (0)</td>
<td>1 (1)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>The buttons and links were easy to understand</td>
<td>S. agree 5 (5)</td>
<td>28 (26)</td>
<td>22 (21)</td>
<td>11 (10)</td>
</tr>
<tr>
<td></td>
<td>Agree 18 (17)</td>
<td>45 (42)</td>
<td>43 (41)</td>
<td>20 (19)</td>
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<tr>
<td></td>
<td>Neutral 3 (3)</td>
<td>5 (5)</td>
<td>2 (2)</td>
<td>6 (6)</td>
</tr>
<tr>
<td></td>
<td>Disagree 1 (1)</td>
<td>0 (0)</td>
<td>1 (1)</td>
<td>1 (1)</td>
</tr>
<tr>
<td></td>
<td>S. Disagree 0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Color was well used in the package</td>
<td>S. agree 5 (5)</td>
<td>37 (35)</td>
<td>29 (27)</td>
<td>13 (12)</td>
</tr>
<tr>
<td></td>
<td>Agree 20 (19)</td>
<td>38 (36)</td>
<td>36 (34)</td>
<td>22 (21)</td>
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<td></td>
<td>Neutral 2 (2)</td>
<td>3 (3)</td>
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<tr>
<td></td>
<td>Disagree 0 (0)</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td>1 (1)</td>
</tr>
<tr>
<td></td>
<td>S. Disagree 0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>The graphics helped me to understand concepts related to the liver</td>
<td>S. agree 9 (8.5)</td>
<td>33 (31)</td>
<td>30 (28)</td>
<td>12 (11)</td>
</tr>
<tr>
<td></td>
<td>Agree 16 (15)</td>
<td>40 (38)</td>
<td>34 (32)</td>
<td>22 (21)</td>
</tr>
<tr>
<td></td>
<td>Neutral 2 (2)</td>
<td>4 (4)</td>
<td>2 (2)</td>
<td>4 (4)</td>
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<tr>
<td></td>
<td>Disagree 0 (0)</td>
<td>2 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td>S. Disagree 0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>The graphics of a high quality and clear</td>
<td>S. agree 7 (7)</td>
<td>28 (26)</td>
<td>24 (23)</td>
<td>11 (10)</td>
</tr>
<tr>
<td></td>
<td>Agree 17 (16)</td>
<td>39 (37)</td>
<td>37 (35)</td>
<td>19 (18)</td>
</tr>
<tr>
<td></td>
<td>Neutral 3 (3)</td>
<td>10 (9)</td>
<td>5 (5)</td>
<td>8 (7.5)</td>
</tr>
<tr>
<td></td>
<td>Disagree 0 (0)</td>
<td>2 (2)</td>
<td>2 (2)</td>
<td>0 (0)</td>
</tr>
<tr>
<td></td>
<td>S. Disagree 0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

Values are the number of students ranking the question; numbers in parentheses are percent of students answering. Groups were studied using the \( \chi^2 \) test. A \( P \) value of <0.05 was considered significant. No \( P \) value was significant.

**Best aspects of the package.** Participants identified the following as the best aspects of the multimedia CD-ROM (most students identified more than 2 items): the animation, graphics, and the liver models (n = 92); the interactive nature of the whole program and how useful it was to their learning (n = 75); the PBL cases (n = 70); the quizzes at the end of each module (n = 67); how the program enhanced their understanding of main concepts and was better than any textbook they had read (n = 67); the glossary (n = 61); the layout of the program (n = 58); and how the program was easy to use and kept them engaged (n = 57).
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Table 7. Rating participant views regarding the PBL cases in module 1 and effects of academic background, gender, citizenship, and first language

<table>
<thead>
<tr>
<th>Statement</th>
<th>Ranking</th>
<th>Academic Background</th>
<th>Gender</th>
<th>Citizenship</th>
<th>First Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases were designed in a way that matches the curriculum</td>
<td>S. Agree</td>
<td>11 (11)</td>
<td>23 (23)</td>
<td>28 (28)*</td>
<td>6 (6)</td>
</tr>
<tr>
<td>Agree</td>
<td>12 (12)</td>
<td>40 (40)</td>
<td>32 (32)*</td>
<td>20 (20)</td>
<td>6 (6)</td>
</tr>
<tr>
<td>Neutral</td>
<td>2 (2)</td>
<td>11 (11)</td>
<td>5 (5)*</td>
<td>8 (8)</td>
<td>6 (6)</td>
</tr>
<tr>
<td>Disagree</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)*</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>S. Disagree</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)*</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>PBL cases kept me engaged</td>
<td>S. Agree</td>
<td>2 (2)*</td>
<td>11 (11)</td>
<td>9 (9)</td>
<td>4 (4)</td>
</tr>
<tr>
<td>Agree</td>
<td>17 (17)</td>
<td>36 (36)</td>
<td>38 (38)</td>
<td>15 (15)</td>
<td>33 (33)</td>
</tr>
<tr>
<td>Neutral</td>
<td>4 (4)</td>
<td>26 (26)</td>
<td>16 (16)</td>
<td>14 (14)</td>
<td>20 (20)</td>
</tr>
<tr>
<td>Disagree</td>
<td>0 (0)</td>
<td>1 (1)</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>S. Disagree</td>
<td>2 (2)</td>
<td>0 (0)</td>
<td>1 (1)</td>
<td>1 (1)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>PBL cases are useful to my learning</td>
<td>S. Agree</td>
<td>2 (2)</td>
<td>13 (13)</td>
<td>12 (12)*</td>
<td>3 (3)</td>
</tr>
<tr>
<td>Agree</td>
<td>17 (17)</td>
<td>40 (40)</td>
<td>41 (41)*</td>
<td>16 (16)</td>
<td>35 (35)</td>
</tr>
<tr>
<td>Neutral</td>
<td>4 (4)</td>
<td>12 (12)</td>
<td>6 (6)*</td>
<td>10 (10)</td>
<td>9 (9)</td>
</tr>
<tr>
<td>Disagree</td>
<td>2 (2)</td>
<td>8 (8)</td>
<td>5 (5)*</td>
<td>5 (5)</td>
<td>5 (5)</td>
</tr>
<tr>
<td>S. Disagree</td>
<td>0 (0)</td>
<td>1 (1)</td>
<td>1 (1)*</td>
<td>0 (0)</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

Values are the number of students ranking the question; numbers in parentheses are percent of students answering. Groups were studied using the χ² test. A P value of <0.05 was considered significant. *p = 0.012; †p = 0.033; ‡p = 0.048.

dia CD-ROM resources must provide a medium different from textbooks, should stimulate student learning, and retain their attention, as well as meet the educational objectives of the course. The multimedia CD-ROM used in this study fulfilled these goals. Use of a wide range of interactive tasks in the multimedia CD-ROM, such as building liver models, a drag and drop exercise, observing the direction of bile and blood flow in a liver model, move transporters to the sinusoidal and canalicular domains, and answering MCQs and scenario-based questions, has enhanced student comprehension of issues discussed and allowed them to apply knowledge gained from basic sciences into clinical situations. The hyperlink provided in the program facilitated integration of the contents and allowed students to search, for example, for difficult terms by using the glossary, visiting pages in other modules when needed, proceeding to the next page, or exiting the system.

It is of interest to note that students enrolled in a PBL course are usually challenged with the structure and design of textbooks and the fact that most undergraduate textbooks are discipline-based and focus on information rather than the enhancement of cognitive skills and application of knowledge. For example, textbooks in basic sciences might ignore the clinical significance of information discussed and their use in understanding of disease pathogenesis and underlying mechanisms. Several recent studies (19, 28, 41, 48) have also identified areas of deficiencies in textbooks and a number of limitations. In a recent article published in Advances in Physiology Education (5), it has been shown that most recommended undergraduate medical textbooks are limited in discussing bile salt transporters, bile formation, and mechanisms underlying cholestasis and drug-induced hepatobiliary dysfunction.

Considering these limitations, the multimedia CD-ROM used in the study has been designed in an innovative way that addressed these needs. The finding that school leavers, particularly those from a non-English speaking background, felt that there was too much information per screen is of interest. The data show that there were no differences in regard to this issue on the basis of citizenship indicating that these differences are most likely related to language competency rather than the learning style of participants. After the completion of the survey in September 2002, the multimedia CD-ROM was reviewed by the author and three medical students, and changes were made to four screens to facilitate the delivery of information in an innovative and gradual way. The use of PBL cases in this multimedia CD-ROM has been found useful by the students and kept them engaged. It also matched with the overall philosophy of the program. No significant differences were found on the basis of citizenship or first language. Compared with graduate-entry students, school leavers showed a more positive attitude toward the PBL cases and agreed that the cases kept them engaged (P = 0.033). In the mean time, the study shows that there were no other significant differences between the two groups in regard to a total of 17 questions (Tables 5–7) and the general comments addressed in the questionnaire used. Furthermore, there were no general comments in the questionnaires collected that give any indication that the use of a CD-ROM or multimedia is of less value to students with a university degree. It may be that the statistically significant difference reflects a “subjective” self-assessment process, whereas the written responses reflect a more “objective” and “elaborative” pattern of participants to these questions. The reason for the differences in perception of the two groups is not clear. It might be that students with a prior university degree prefer small group discussion of PBL cases and collaborative learning, whereas school leavers prefer working on PBL cases on their own. This might partly explain the difference observed in this study; however, the explanation provided is hypothetical and needs further study.

The findings also indicate gender differences in regard to perception. Female students compared with males agreed that the PBL cases matched with the philosophy of the course (60 females vs. 26 males, P = 0.012) and were useful to their learning (53 females vs. 19 males, P = 0.048). The effect of
gender on student perception about interprofessional PBL courses has recently been raised (39). Reynolds (39) also found that women expressed greater enjoyment at taking responsibility for their own learning and had more positive views about working with students from another course.

The use of the MCQs test in the study aimed at the assessment of understanding of main learning concepts related to the liver, bile salts, and bilirubin metabolism. The questions included in this test were free from grammatical clues (4). The results show that compared with the control group, the mean test results of group 1 (students attended 6 lectures and completed a PBL case on breast milk jaundice in their groups plus attended Tutorial 1 of the PBL cases on liver cirrhosis and used the multimedia CD-ROM before undertaking the test) and group 3 (students completed 11 lectures, two PBL cases, Tutorial 1 of a PBL case covering the role of the liver in drug metabolism, and the MCQs after using the multimedia CD-ROM) were significantly different (P < 0.001 for each). This indicates that curriculum material and the multimedia CD-ROM have improved their performance in the test. However, it appears that the lectures and curriculum material alone did not significantly improve student performance in the test (group 2 vs. control, P = 0.084). At the same time, the mean test results of group 3 were significantly higher compared with those of group 2 (P < 0.001), indicating significant improvement in the mean test results after using the multimedia CD-ROM.

Furthermore, the test results of group 2 were significantly lower compared with those of group 1 (P = 0.014), and the mean test results of group 1 were not significantly different from those of group 3 (P = 0.613), which may indicate that the multimedia CD-ROM alone was able to enhance their test results.

One might hypothesize that the MCQs used in the test addressed topics included in the multimedia CD-ROM rather than those of the curriculum. This is less likely to be the case, because the test questions were focused on main concepts discussed in the problem of the week and were not focused on minute details. However, the higher mean test scores of group 3 students compared with those of group 2 (16.6 ± 5.2 vs. 10.1 ± 2.8) are not necessarily related to specific advantages of the multimedia CD-ROM contents over the curriculum material addressed in these weeks. The explanation is most likely related to the wide range of interactive tasks provided in the multimedia CD-ROM. These interactive tasks enhanced student understanding of main concepts discussed in PBL tutorials, exposed them to a wide range of exercises, tested their higher-order cognitive skills, and allowed them to think conceptually. These effects might explain why mean scores of group 3 students were higher.

In conclusion, using bile salts, bilirubin metabolism, and their hepatobiliary transport as an example, the incorporation of a multimedia CD-ROM into the first-year medical course has the potential to improve student understanding of the main concepts in a variety of body systems. Additional studies are needed to compare the effects of using such tools in medical and health education on long-term competency and higher-order cognitive skills.

ACKNOWLEDGEMENTS

The author thanks the first-year medical students at the University of Melbourne who participated in this study; colleagues at the Faculty Informa-

tion Technology Unit and Biomedical Unit for their help and support during the preparation of the multimedia CD-ROM used in this study, particularly the graphic designers of the project Andrew Bonollo and Avril Martinelli and the project managers Dr. Mike Keppell and Kevin Sweeney; reviewers of the contents of the CD-ROM Professors Prithi Bhathal and Roy Robins-Browne and Drs. Norman Eizenberg and Howard Grossman; and Prof. Peter Harris and Assoc. Prof. Susan Elliott for encouragement and support during the preparation of the grant application for the multimedia CD-ROM project. Drs. Gregor Kennedy and Mike Keppell kindly provided advice during the preparation of the questionnaire for this study. The author also thanks fifth-year medical students Adam Pendlebury, Lindy Washington, and Rowena Christiansen for valuable comments on “The Liver” CD-ROM; and Dr. Barbara Goodman, the Associate Editor of Advances in Physiology Education, and the three reviewers of the manuscript for their constructive comments on the paper and useful feedback.

GRANTS

“The Liver” CD-ROM was funded by a grant from Teaching and Learning Medical and Educational Technology Committee Grants, the University of Melbourne, Victoria, Australia.

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