Adv Physiol Educ 28: 15–22, 2004;
10.1152/advan.00019.2002.

An evaluation of case-based teaching: evidence for continuing benefit and realization of aims

J. N. Hudson[1] and P. Buckley[2]

[1]*Peninsula Medical School, Plymouth PL6 8BX, United Kingdom; and*
[2]*Adelaide University, Adelaide, South Australia 5005, Australia*

Received 15 April 2002; accepted in final form 3 October 2003

Hudson, J. N., and P. Buckley. An evaluation of case-based teaching: evidence for continuing benefit and realization of aims. *Adv Physiol Educ* 28: 15–22, 2004; 10.1152/advan.00019.2002.—A cross-sectional evaluation of case-based teaching (CBT), a novel physiology learning environment for medical undergraduates, revealed that second, third, and fourth year students, together with their tutors, valued CBT as an experience that met its three major aims. The initiative not only integrated physiology with related basic sciences and clinical medicine but importantly linked students' developing knowledge of theory to practice. CBT was also valued by students as their first introduction to clinical skills, with most tutors believing that it was the nonthreatening environment that helped students gain confidence for their first "real patient" encounters. The greatest support for CBT came from third year medical students, at the crossroads between their preclinical and clinical environments. Fourth year students, now encountering real patients, had moved on to developing their skills in the hospital environment.

medical education; theory-practice link; integration; confidence

FOR THE UNDERGRADUATE MEDICAL STUDENT, the journey from school leaver to competent medical practitioner has many challenges and hurdles along the way. Margetson (10) described learning to become a thoroughly competent practitioner as ". . .the development of an integrated, coherent "growing web" of understanding, knowledge and skill." For the undergraduate, early learning environments play a critical role in laying the foundation for "this web" and developing students' confidence to undertake the journey through to competence. The case-based teaching (CBT) environment, recently described in *Advances in Physiology Education* (9), was one such learning environment. It was an early educational intervention in the hybrid or complementary (6) medical curriculum at the University of Adelaide, designed and implemented in the department of Physiology, over the five years before the introduction of a new integrated curriculum in 2000.

In 1995, the first three years of the medical curriculum consisted mainly of traditional learning strategies, complemented by a smaller, problem-based learning (PBL) stream, in which students "worked through" some virtual or paper cases. Clinical skills were not introduced until third year, after most of the students' basic science training was complete. The human structure and function stream consisted of physiology and anatomy large-group lecture and clinical correlation sessions, and traditional anatomy practicals. In first year human structure and function, the physiology "practical component" consisted of research-based practicals. In second year, we wished to offer medical students a practical experience that was valid for their future vocation, where they could learn clinical skills in a supportive environment, not emphasising the "performance" aspect but more in terms of understanding how these skills can reveal information on an individual's structure and function.

Learning was placed in the context of a case to give meaning to the tasks and material that students were acquiring, while integrating their theoretical knowledge and understanding of the basic and clinical sciences. Integration is a key issue in medical undergraduate programs (11). Although there are many meanings given to this concept, Mortenson cites Bruner's view that true integration means that the learner continually connects practice and theory (11). That is, practical experience is closely combined with conceptual explanations of what is done.

The CBT initiative first aimed to integrate basic and clinical science theory by making it case based, also one of the aims of the PBL learning stream. CBT cases were chosen to raise important learning issues in human structure and function, but by liaising with the PBL convenor they could also complement learning experiences in PBL during the same semester. For example, a CBT case on obstructive jaundice was a rich source of learning issues in liver structure and function and bilirubin metabolism, but it complemented learning from a PBL case on viral hepatitis. However, CBT linked the theoretical case content with the skills that were needed for its evaluation. This step was taken to show students how their theoretical knowledge underpinned history taking and physical examination and interpretation of the investigations. With an understanding of how symptoms and signs were derived, we hoped that they would use their knowledge to formulate more meaningful case hypotheses. Similarly, when interpreting investigations, such as lung function tests or ECG tracings to test hypotheses, performing them should lead to an appreciation of both their bases and their limitations.

As discussed in previous reports (8, 9), CBT tutors introduced students to clinical skills in a way that aimed to build confidence for their first "real" patient encounters by providing an environment where they would feel safe to try these practical activities, together with their peers. An early evaluation, completed by one cohort of second year students, revealed that it was highly valued by these students in terms of a series of stated learning objectives (9), and those students reported varying degrees of confidence development. However, because development into a competent practitioner takes place gradually and at different rates for different learners, a cross-sectional study spanning a three-year period was planned to determine whether the value that students placed on the CBT

Address for reprint requests and other correspondence: J. N. Hudson, Peninsula Medical School, St. Lukes, Exeter EX1 2LU, United Kingdom (E-mail: nicky.hudson@pms.ac.uk).

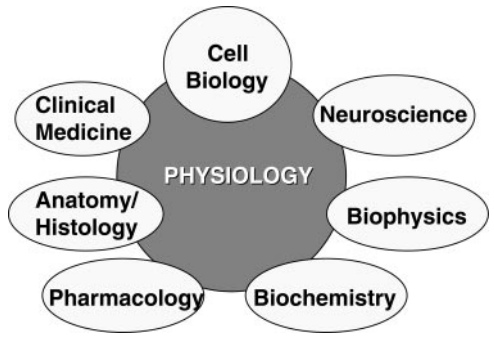

Fig. 1. Relation between physiology and related medical sciences [Sefton (14)].

learning environment depended on their stage of professional development. This problem-based, small-group, cooperative-learning environment was valued by the authors, but how was it perceived by three successive years of undergraduate students and their tutors?

METHODS

At the end of the 2000 academic year, three cohorts of students and a cohort of CBT tutors were asked, with their informed consent, to complete an evaluation of the CBT initiative.

Student sample. The students, although a culturally diverse group, had a similar educational background in that most of them had proceeded to undergraduate medical studies straight from high school. The three cohorts were as follows.

1) Second year medical undergraduates who, during 2000, took part in CBT tutorials concurrent with their traditional learning experiences (lectures and practicals) in human structure and function of the cardiovascular, respiratory, gastrointestinal, and renal systems. This was before the commencement of their formal clinical skills learning experiences in third year. Eighty-five students (63% of the class) completed the questionnaire at the end of one of their final second year lectures.

2) Third year medical undergraduates who had completed the second year CBT tutorials in 1999. In 2000, they commenced formal clinical skills training and attended additional CBT tutorials concurrent with their traditional learning experiences in human structure and function of the nervous system. Third year CBT remained an introductory experience, linking neuroscience to neurology, as it preceded their clinical skills tutorials in neurology. One hundred and five students (78% of the class) completed the questionnaire at the end of their final CBT tutorial.

3) Fourth year medical undergraduates who had completed the second- and third year CBT tutorials in 1998 and 1999, respectively. At the time of the evaluation, they had undertaken various clinical attachments as part of the fourth year clinical curriculum. Sixty-four students (56% of the class) completed the questionnaire when gathered together for one of their final fourth year assessments.

Tutor sample. Nine teachers, who were recent or current CBT tutors, completed the questionnaire. All tutors had attended small-group and/or PBL tutor training, and also attended a training session on tutorial content, before each new CBT tutorial. They were a diverse

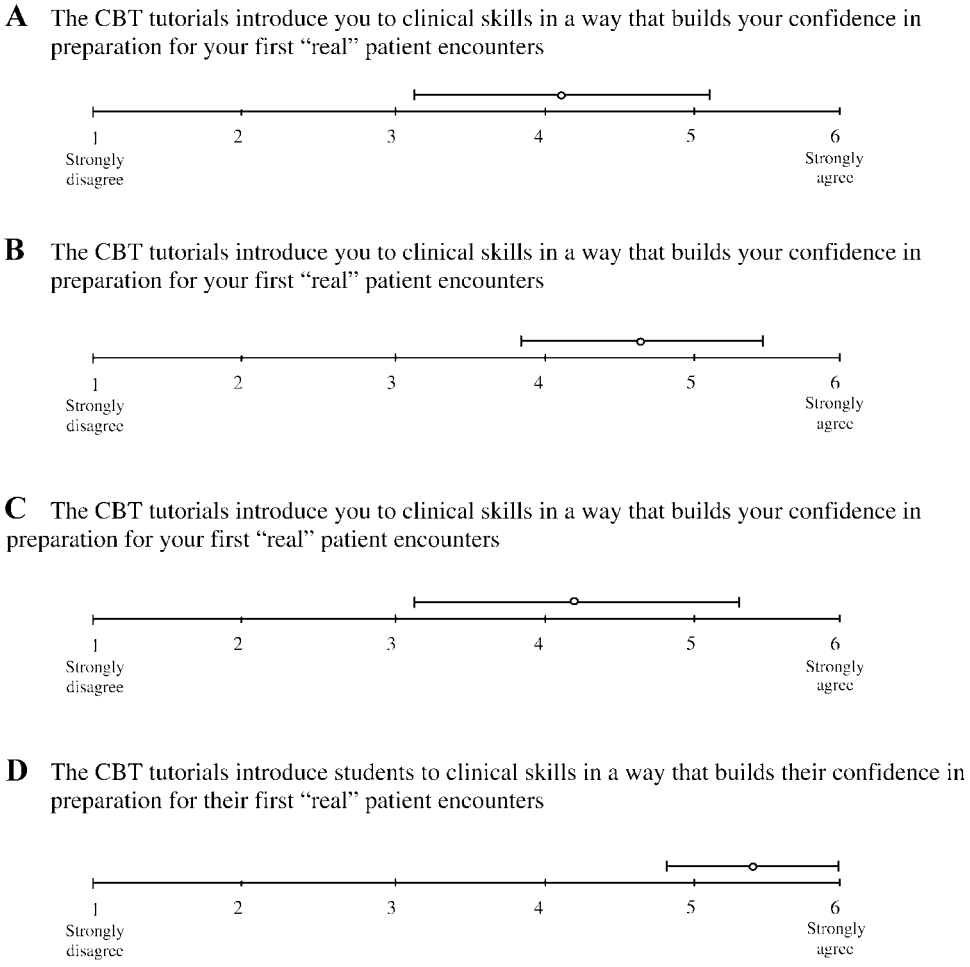

Fig. 2. Responses from 85 2nd-yr students (*A*), 105 3rd-yr students (*B*), 65 4th-yr students (*C*), and 9 tutors (*D*) at Adelaide University regarding *aim 1* of the case-based teaching (CBT) tutorials.

group with regards to age, sex, cultural background, and experience. Their educational backgrounds comprised the following: three recent medical graduates in current hospital clinical practice and also teaching in third year PBL and clinical skills tutorials; two specialist-trained doctors, not in current medical practice but active in a variety of undergraduate teaching initiatives such as anatomy practicals and PBL tutorials; two research scientists, trained in veterinary medicine, with a large teaching experience in both large- and small-group teaching environments, such as PBL tutorials; and two medically qualified tutors following a career in medical and health science education but not in current clinical practice.

Questionnaire. Students and tutors were invited to complete a questionnaire and comment whether, in their experience, the CBT tutorials had met the following three defined aims: *1*) to introduce students to clinical skills in a way that built student confidence, in preparation for the first real patient encounters; *2*) to strengthen the link between the theory and practice of medicine so that students could see how the questions in the clinical history, the tasks in the physical examination, and the interpretation of investigations are derived from an understanding of normal structure and function; *3*) to achieve integration of knowledge between medical sciences and clinical medicine.

Aims 2 and *3* were of particular interest to our discipline. Because physiology teaching before the CBT initiative was either discipline based or integrated only with structure, we were interested to receive student feedback on the value of extending the integration. Figure 1, an illustration from Sefton's article on the future of teaching physiology (14), demonstrates the potential for physiology to integrate basic science theory with the theory of clinical medicine. By situating CBT learning in the context of a clinical problem, we aimed to exploit physiology's potential to integrate knowledge of normal body processes in health with those in disease (pathophysiology). *Aim 3* describes this integration at the level of knowledge or theory. However, *Aim 2* took the integration one step further, by connecting this theory with practice.

In the questionnaire, administered by an independent staff member, students and tutors were asked to make a value judgement in relation to the three aims on a Likert scale of 1 to 6 (1 = aim not met, 6 = aim fully achieved). Students were also invited to indicate which particular aspects of CBT were useful to them (in relation to the aims), whereas tutors were invited to reflect on their perception of how CBT may have contributed to achieving the aims of the learning experience.

Although not all students responded to the open-ended questions or responded in relation to the relevant aim, this component of the evaluation invited spontaneous elaboration on CBT's success in meeting its aims, as well as personal reflection on aspects of the learning environment that were useful. The student questionnaires were administered, collected, and collated for analysis by persons indepen-

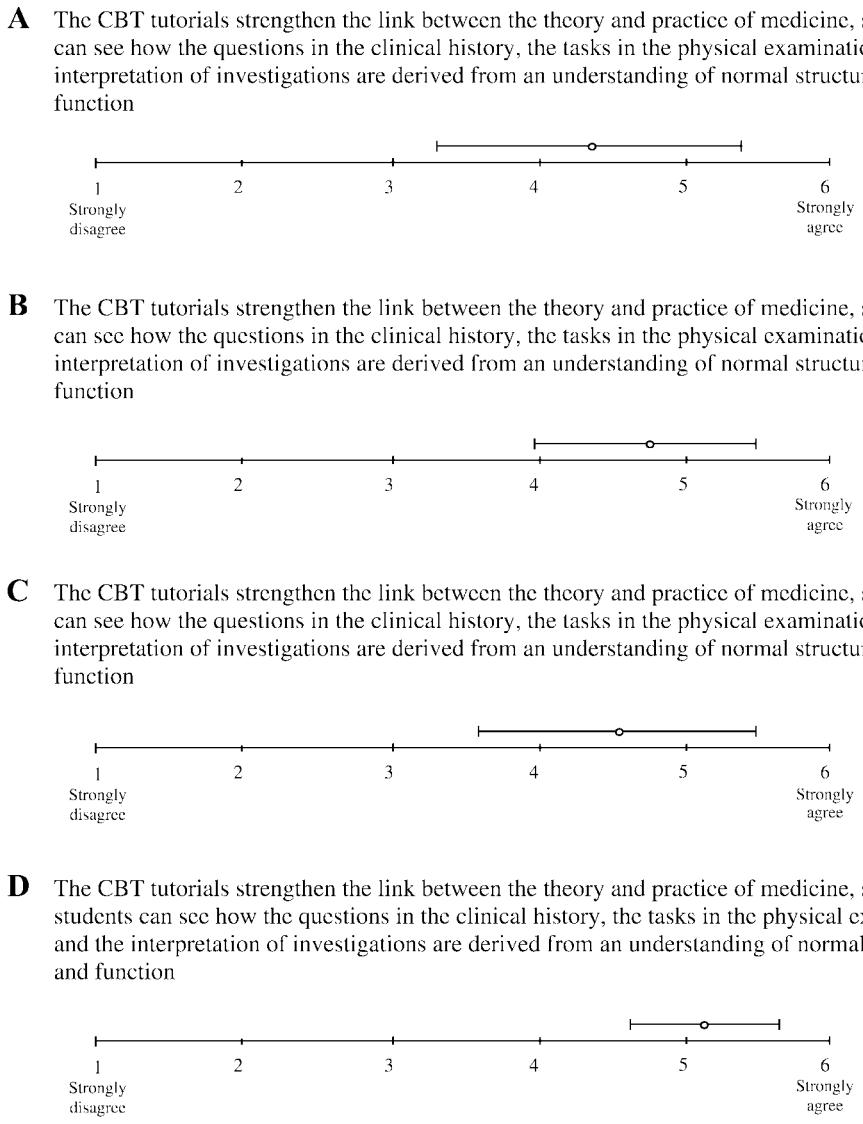

Fig. 3. Responses from 85 2nd-yr students (*A*), 105 3rd-yr students (*B*), 65 4th-yr students (*C*), and 9 tutors (*D*) at Adelaide University regarding *aim 2* of the CBT tutorials.

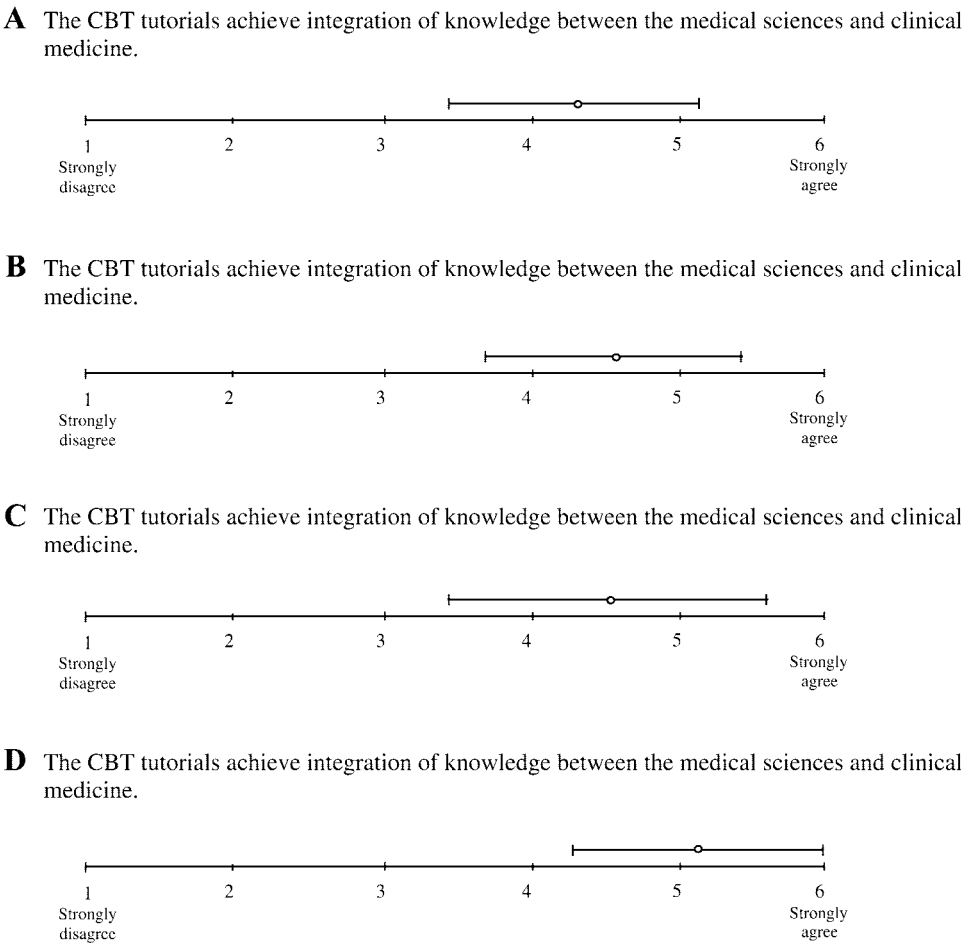

Fig. 4. Responses from 85 2nd-yr students (*A*), 105 3rd-yr students (*B*), 65 4th-yr students (*C*), and 9 tutors (*D*) at Adelaide University regarding *aim 3* of the CBT tutorials.

dent of the researchers. Questionnaires were distributed and collected from tutors by mail. Although tutors had some stake in the success of the learning environment, they were invited to, and did make, candid comments in relation to CBT. Both student and tutor content analyses of the qualitative data were completed by an educational psychologist with no vested interest in the research outcomes. Each analysis was performed by reviewing all the comments in relation to the aims of the CBT initiative. Individual responses were coded, with similar responses from other students/tutors being coded by the same number. From this, the number of students/tutors making similar responses could be calculated.

Statistical analysis. For each of the three CBT aims, the means of the tutors' and students' value judgments (Likert Scale 1 to 6) were compared using the Krustal-Wallis *H*-test for nonparametric data (with SPSS, version 10).

RESULTS

Quantitative data. The means and SD of the student and tutor value judgements in relation to the three aims are illustrated in Figs. 2, 3, and 4. For each aim, the mean response value is shown by the circular symbol, and the SD is shown by the bar extending from the mean value.

Statistical analysis. Tables 1, 2, and 3 show the comparison between the rankings of all three groups of students and the tutors for *aims 1–3*, respectively. For *aim 1*, there was a significant difference between the responses of the four groups (Table 1). The mean rank statistics revealed that CBT was most highly valued as an environment in which to build confidence for the first real patient encounters, by tutors then third, fourth, and second years in descending order. For *aim 2*, the differences approached, but did not achieve, significance (Table 2).

Qualitative data. The content analyses of student and tutor data are presented in a series of tables (Tables 4 through 9) to facilitate comparison of each student year group and tutor responses. Because some students and tutors made more than one comment in relation to each aim, in all tables, the number of comments is greater than the number of students.

DISCUSSION

At The University of Adelaide, CBT was planned at a time when teaching contact time had just been reduced to allow learners more time for self-directed learning. Although many medical schools have introduced early clinical exposure to

Table 1. *Comparison between tutor and student rankings of aim 1 (Krustal-Wallis H-test)*

Group	*N*	Mean Rank
Tutors	9	210.61
Students 3rd yr	106	148.37
Students 4th yr	64	121.46
Students 2nd yr	84	110.95
Total	263	

$P < 0.001$.

Table 2. *Comparison between tutor and student rankings of aim 2 (Krustal-Wallis H-test)*

Group	*N*	Mean Rank
Tutors	9	173.33
Students 3rd yr	104	138.39
Students 4th yr	64	130.04
Students 2nd yr	84	118.04
Total	261	

$P < 0.054$.

benefit students' personal development as well as the acquisition of clinical skills (13), at our school in 1995, clinical skills training was delayed until third year. With a curriculum still comprising many traditional learning strategies, a new opportunity arose for physiology education. We could help medical undergraduates, at the outset of their clinical skills training, acquire a "usable" knowledge of human function, one where an understanding of theory is integrated with practice. After considerable effort and planning, CBT was implemented. Next, a comprehensive evaluation was required.

A study was designed to evaluate the impact of CBT on three successive cohorts of medical undergraduates, with each cohort at different stages of its members' professional development. These cohorts were chosen, as second year students could reflect on CBT as their first practical experience, third year students could provide a perspective from students in transition between the preclinical and clinical learning environments, and fourth year students had the wisdom of their first clinical year. Feedback from tutors, partners with students in the learning process, was gathered to enrich the findings of the study.

The varying response rates from the three student groups probably reflect the different methods in which data were collected from each student group at the end of an academic year. It may also reflect varying enthusiasm for CBT, as suggested by the results. At the final CBT tutorial, an administrator distributed the questionnaires to all third year students and had a "captive audience" with a high response rate for this group. Second year students completed the questionnaires at a large-group lecture and a reasonable response rate from gained from them. Because it proved difficult to access fourth year students, spread out in clinical attachments at a variety of institutions, they were asked to complete the questionnaire when gathered before a final year-four assessment. This was far from ideal, as many students were unwilling to engage at that time, especially in providing qualitative data, but it became the best option.

The students' subjective evaluations were valued highly. As young adults with "privileged access to their own thoughts,"

Table 3. *Comparison between tutor and student rankings of aim 3 (Krustal-Wallis H-test)*

Group	*N*	Mean Rank
Tutors	9	174.78
Students 3rd yr	101	132.48
Students 4th yr	64	128.22
Students 2nd yr	81	117.04
Total	255	

$P < 0.081$.

Table 4. *Comments about aim 1 by 79 2nd-yr (93%), 104 3rd-yr (99%), and 54 4th-yr students (85%)*

Theme	2nd-yr Students, *N* (%)	3rd-yr Students, *N* (%)	4th-yr Students, *N* (%)
Built confidence	18 (23)	31 (30)	9 (17)
Did not build confidence	13 (16)	8 (8)	6 (11)
Nonthreatening/interesting environment	16 (20)	12 (12)	5 (9)
Good introduction to practice & equipment	21 (27)	15 (14)	14 (26)
Need more time or practice	23 (29)	12 (12)	0
Use real or simulated patients	10 (13)	9 (9)	11 (20)
Good to practice on colleagues	5 (6)	21 (20)	2 (4)
Depended on tutor	7 (9)	0	0
Positive comments about tutor	7 (9)	0	0
Negative comments about tutor	5 (6)	0	0
Positives of teaching method & outcomes	0	22 (21)	10 (19)
Criticisms of method	15 (19)	10 (10)	11 (20)
Hospital/ward teaching better	0	6 (6)	0
Total no. of comments	141	146	78
No. of themes	11	10	8

they are capable of self-reflection and control over their thinking and past experiences (16). With suitable training such as sufficient modeling and coaching, students can become "well equipped" to comment perceptively on their own learning and provide sensible and valuable information on new instructional methods. Students' value judgements informed a majority opinion on the success of the CBT in relation to the articulated aims.

Learners were first asked to reflect on whether CBT had built their confidence for real patient encounters. As defined by Stewart et al. (15), "confident" describes ". . .a judgement which influences whether an individual is willing or not to undertake an activity." In CBT, where students faced many new tasks including the important step of making the first professional physical contact with a "patient," tutors played an

Table 5. *Comments about aim 1 by 9 tutors (100%)*

Theme	Tutors, *N* (%)
Built confidence	8 (89)
Partially built confidence	1 (11)
Nonthreatening environment	9 (100)
Was supportive and relaxed learning environment that fostered confidence/allowed time for gradual emergence of skills	7 (78)
Preparing for clinical years/breaking down the preclinical-clinical divide	4 (44)
Fun, enjoyable for students	2 (22)
Importance of carefully handling peer-peer examination environment	2 (22)
Students will realize impact on confidence acquisition in retrospect, if not now	1 (11)
Total no. of comments	34
No. of themes	9

Table 6. *Comments about aim 2 by 72 2nd-yr (85%), 98 3rd-yr (87%), and 47 4th-yr students (73%)*

Theme	2nd-yr Students, *N* (%)	3rd-yr Students, *N* (%)	4th-yr Students, *N* (%)
Strengthened link between theory and practice	47 (65)	61 (62)	15 (32)
Partially strengthened link between theory and practice	4 (6)	8 (8)	11 (23)
Did not strengthen link between theory and practice	3 (4)	3 (3)	0
Good practice	0	10 (10)	0
Criticisms of method, including not enough time	14 (19)	12 (12)	18 (38)
Positives re teaching/method	0	6 (6)	14 (30)
Praise for tutors	11 (15)	6 (6)	0
Criticism of tutors	8 (12)	0	0
Total no. of comments	87	114	58
No. of themes	6	7	4

Table 8. *Comments about aim 3 by 57 2nd-yr (67%), 75 3rd-yr (71%), and 54 4th-yr students (61%)*

Theme	2nd-yr Students, *N* (%)	3rd-yr Students, *N* (%)	4th-yr Students, *N* (%)
Integrated medical sciences with clinical medicine	22 (39)	54 (72)	20 (51)
Partially achieved integration	10 (18)	0	4 (10)
Did not achieve integration	5 (9)	9 (12)	2 (5)
Need more sessions/time	7 (12)	7 (9)	0
Criticism of tutor/depends on tutor	12 (21)	0	0
Depends on student	1 (2)	0	0
Positive comments re teaching/method	0	0	2 (5)
Criticism of teaching/method	0	0	3 (8)
Total no. of comments	68	76	37
No. of themes	7	4	6

important role in providing a setting in which they were willing to "have a go," and not fear being humiliated in front of their peers.

As well as fostering a safe, supportive environment where novices from diverse cultural backgrounds felt confident to undertake and acquire new practical skills, tutors had to be aware of the rights of students, especially in peer-to-peer physical examinations.

Braunack-Mayer (1) reminds us of some of the ethical implications of allowing students to act as surrogate patients for each other. By having to be a patient, students learn a lot about respecting patients. In the next stage of their clinical skills development, students expect to practice on patients. However, just as patients need to consent to examination by students, students must not be coerced in to acting as surrogates for their peers. Some of the male students complained about not having many opportunities to examine their female colleagues. Although examining patients of the opposite sex can be a major hurdle for young students, tutors preferred to invite students to "be a patient" rather than insist that students of either sex adopt the role. Students could choose to be a patient or a doctor when they were ready, and many students valued the CBT tutors' sensitivity to this issue.

Tutors believed that they provided a relaxed, nonthreatening environment, which fostered confidence and allowed for the gradual emergence of clinical skills (Table 5), and believed that CBT was a learning environment that introduced students to clinical skills in a way that built their confidence for future patient encounters (Fig. 2). One tutor, a recent medical graduate, added that ". . .students will be able to approach more threatening clinical situations in future with a solid background experience. Students may not fully realise it now—but they will in retrospect." This is an interesting comment in relation to student responses. All student cohorts agreed that CBT had contributed to confidence building, but it was the third year students at the crossroads of their CBT and clinical skill experiences who gave the strongest student support to the achievement of *aim 1*. They were currently facing clinical situations with a background of CBT experience. These conclusions are supported by statistical comparison of the quantitative judgements and the spontaneously generated positive comments that third year students made about CBT and practising on colleagues.

Second year students, with no previous experience of the material and tasks and yet to encounter "real patients," acknowledged that CBT provided a nonthreatening environment, with opportunities for practice of clinical skills (Tables 4 and 5), but many felt that more time for this introductory initiative was needed to foster their confidence for the next step. The level of their response was similar to that given by an earlier second year cohort in a preliminary evaluation (9). Costs associated with mounting small group initiatives and competing demands for student contact time were just some factors impacting on the time allocated to CBT. However, because students need time to learn at a rate commensurate with their self-confidence and perceived competence, for some, inadequate time allocation could have negatively influenced their ability to gain confidence from the experience.

Fourth year students, who also commented positively about the CBT as an introductory experience, were now developing

Table 7. *Comments about aim 2 by 9 tutors (100%)*

Theme	Tutors, *N* (%)
Strengthened link between theory and practice	8 (89)
Partially strengthened link between theory and practice	1 (11)
Students able to see relevance of the theory they are learning	5 (56)
Clinical case was framework for achieving the aim	4 (44)
Helped put theory into long-term memory	1 (11)
Criticism of students (not preparing for session or using opportunities in session)	2 (22)
Total no. of comments	21
No. of themes	6

Table 9. *Comments about aim 3 by 9 tutors (100%)*

Theme	Tutors, *N* (%)
Integrated medical sciences with clinical medicine	7 (78)
Partially achieved integration	2 (22)
Once again, clinical case helped to achieve the aim	4 (44)
Showed relevance of all the theory from the different disciplines	4 (44)
Total no. of comments	17
No. of themes	4

their confidence in the hospital environment with "real patients." For them, CBT seemed less important, as they had more experience and felt more competent with the tasks.

However, becoming a competent medical practitioner is about more than merely acquiring clinical skills. Having confidence and competence in history taking and physical examinations but being unable to attach meaning to the findings does not define an effective medical practitioner. Equally ineffective is someone who is full of book learning but unable to put it into practice. As discussed in the introduction, a competent practitioner has an integrated, coherent web of understanding, knowledge, and skill.

Physiology, with its obvious relationships to other medical science disciplines, lies at the heart of the knowledge base that a practitioner uses in intelligent judgement. Although an understanding of human function is an integral part of the evaluation of a clinical case, this understanding is not used in isolation from that of other medical and clinical sciences. In CBT, by teaching human function in the context of a case, physiology was integrated with an understanding of the other disciplines need to solve the case. The instructional method, with a self-directed learning component, taught students the content of the discipline and the relevant skills needed to handle that particular content competently at the same time. Empirical support (2, 4, 12) for the value of this method has come from cognitive and educational psychologists in the 1980s.

At a time when much of the curriculum at the University of Adelaide was still discipline based, was CBT valued as an integrative learning environment? Responses from second year students revealed that many did not clearly understand the aim (21% of respondents were independently judged to have misunderstood the question). CBT was only their second experience of an integrated learning environment, and although the aim clearly states that it is about integration at the level of knowledge, this could have been further emphasized in verbal instructions to these more novice students. However, third- and fourth year students, together with tutors, acknowledged that CBT had integrated the medical sciences with clinical medicine (Tables 8 and 9). Some students commented that this had been particularly valuable when the CBT cases were temporally related to PBL cases. An example of how PBL has complemented CBT has been given in the introduction.

Like Hager et al. (5), the authors believe that ". . .integration of the theoretical and practical is at the heart of successful professional practice." To foster this integration and close the theory-practice gaps that were evident at that time in our curriculum, we wished to temporally associate structured training in core skills with the acquisition of the knowledge that underpinned it.

In terms of linking theory to practice, CBT has been judged to be successful by several cohorts of students, and tutors (Fig. 3), and there was no statistical difference between the rankings of these groups. This aim (*aim 2*) received the greatest support, pleasing in that linking theory to practice was the original driving force for the development of the CBT initiative. Over 60% of second- and third year students spontaneously made positive comments about this aspect of CBT (Tables 6 and 7), many claiming that it supported their concurrent theoretical learning in second and third years. In the progression from novice to competent graduate, being able to understand human function and use this understanding to interpret findings in clinical practice must further add to a student's growing self-confidence.

Positive and negative comments were made about tutors (Tables 4–9), especially by second year students. A tutor's behavior, together with the quality of the problem and student's prior knowledge, can affect how a small group functions (3). Tutors were rotated between groups each semester to reduce the impact of less effective tutors on individual students. One can speculate that second year students, who were less advanced in their development, were more reliant on tutor facilitation, but no such conclusions can be drawn from this evaluation. The focus of this study was the learning outcomes associated with CBT.

Although students commented on tutors in the evaluation, only one comment was made by a student about students (Table 8) and two by tutors about students (Table 7). Obviously, students who prepared for and actively took part in the sessions stood to gain more from the experience. It would have been useful to ask students to evaluate their own contribution to the success of the CBT initiative. Self-evaluation is an important part of professional development and encourages students to reflect on their responsibilities in the learning process.

In summary, CBT was an innovative environment for teaching medical undergraduates a "usable" knowledge of physiology in the human structure and function course of the hybrid curriculum at the University of Adelaide. While applying current knowledge about learning, it had some novel aims in physiology education. In addition to integrating physiology with related disciplines, it aimed to ensure that medical undergraduates' early practical experience was closely combined with conceptual explanations of what was done, in an environment where students developed some confidence to start the journey through to competence. Although students and tutors valued the educational experience in a hybrid curriculum, the concept of linking theory to practice is relevant for all medical curricula.

ACKNOWLEDGMENTS

We thank the medical students and tutors who participated in the evaluation, Amanda Hart from the Physiology Learning and Teaching Centre for her assistance in collating the data, Professor Caroline McMillen for creative input into the study design, and Suzanne Chamberlain, a colleague at Peninsula Medical School, for completing the statistics.

GRANTS

The evaluation was conducted with the support of a Faculty of Science Teaching Development Grant.

REFERENCES

1. **Braunack-Mayer A.** Should medical students act as surrogate patients for each other? *Med Educ* 35: 681–686, 2001.
2. **Brown JS, Collins A, and Duguid P.** Situated cognition and the culture of learning. *Educ Res* 18: 32–42, 1989.
3. **Gijselaers WH and Schmidt HG.** Development and evaluation of a causal model of problem-based learning. In: *Innovation in Medical Education: An Evaluation of Its Present Status*, edited by Nooman AM, Schmidt HG, and Ezzat ES. New York: Springer, 1990, p. 95–113.
4. **Glaser R.** The maturing of the relationship between the science of learning and cognition and educational practice. *Learn Instruct* 1: 129–144, 1991.
5. **Hager P, Gonczi A, and Athanasou J.** General issues about assessment of competence. *Assess Eval Higher Educ* 19: 3–16, 1994.
6. **Harden RM.** Integrated teaching—what do we mean? A proposed taxonomy. *Med Educ* 32: 216–217, 1999.

7. **Hendry GD, Lyon PM, and Gordon J.** Students evaluation of expert and non expert problem-based learning tutors. *Med Teacher* 24: 544–549, 2002.
8. **Hudson JN.** Integrating the art, and science of medicine in the early stages of medical education. *Med Educ* 34: 954, 2000.
9. **Hudson JN, Buckley P, and McMillen IC.** Linking cardiovascular theory to practice in an undergraduate medical curriculum. *Adv Physiol Educ* 25: 193–201, 2001.
10. **Margetson DB.** The relation between understanding and practice in problem-based medical education. *Med Educ* 33: 359–364, 1999.
11. **Martenson D.** Learning: current knowledge and the future. *Med Teacher* 23: 102–107, 2001.
12. **Perkins DN and Salomon G.** Are cognitive skills context-bound? *Educ Res* 18: 16–25, 1989.
13. **Salafsky B and Boelen C.** Planning a community-oriented, cost-effective medical school. *Educ for Health* 23: 307–318, 1996.
14. **Sefton A.** The future of teaching physiology: an international viewpoint. *Adv Physiol Educ* 20: S53–S58, 1998.
15. **Stewart J, O'Halloran C, Barton JR, Singleton SJ, Harrigan P, and Spencer J.** Clarifying the concepts of confidence and competence to produce appropriate self-evaluation measurement scales. *Med Educ* 34: 903–909, 2000.
16. **Volet S.** Modelling and coaching of relevant metacognitive strategies for enhancing university students' learning. *Learn Instruct* 1: 319–336, 1991.