Comparison of computer-assisted instruction (CAI) versus traditional textbook methods for training in abdominal examination (Japanese experience)

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PURPOSE This study aimed to compare the effects of computer-assisted, text-based and computer-and-text learning conditions on the performances of 3 groups of medical students in the pre-clinical years of their programme, taking into account their academic achievement to date. A fourth group of students served as a control (no-study) group.

METHOD Participants were recruited from the pre-clinical years of the training programmes in 2 medical schools in Japan, Jichi Medical School near Tokyo and Kochi Medical School near Osaka. Participants were randomly assigned to 4 learning conditions and tested before and after the study on their knowledge of and skill in performing an abdominal examination, in a multiple-choice test and an objective structured clinical examination (OSCE), respectively. Information about performance in the programme was collected from school records and students were classified as average, good or excellent. Student and faculty evaluations of their experience in the study were explored by means of a short evaluation survey.

RESULTS Compared to the control group, all 3 study groups exhibited significant gains in performance on knowledge and performance measures. For the knowledge measure, the gains of the computer-assisted and computer-assisted plus text-based learning groups were significantly greater than the gains of the text-based learning group. The performances of the 3 groups did not differ on the OSCE measure. Analyses of gains by performance level revealed that high achieving students' learning was independent of study method. Lower achieving students performed better after using computer-based learning methods.

CONCLUSION The results suggest that computer-assisted learning methods will be of greater help to students who do not find the traditional methods effective. Explorations of the factors behind this are a matter for future research.

KEYWORDS education, medical undergraduate/*methods; computer assisted instruction/methods; clinical competence/standards; curriculum; students, medical.

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INTRODUCTION

The purpose of this study was to assess the effectiveness of computer-assisted instruction (CAI) compared to the effectiveness of more traditional, text-based methods.

Computers have been used as a learning tool in education since the 1950s. Skinner[1] was among the first to recognise and report on the potential in the technology for great improvement in educational methods. The original 'Skinner box', which provided a controlled and predictable environment, was soon transformed into a 'teaching machine'. In the mid-1960s, the teaching machines were replaced by computers entirely. Computer-assisted instruction

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Overview

What is already known on this subject

Computer-assisted instruction has gained wide acceptance as a teaching method. The efficacy of CAI, however, remains controversial.

What this study adds

This study provides evidence that properly designed CAI can be superior to traditional textbook learning. In addition, we found CAI to be especially effective for people who have difficulties learning with traditional methods.

Suggestions for further research

Future studies should address longterm retention of knowledge gained with CAI and the factors underlying individual differences in the ability to assimilate and retain knowledge using CAI, and should evaluate the effectiveness of CAI in the context of medical school curricula.

provided a better learning environment and gained popularity in education circles.[2,3] This new concept promoted the idea that computers should assist teachers in achieving an instructional goal. Advances in computer technology meant that during the 1980s the education market was penetrated by intelligent tutoring systems (ITS).[4,5] These programs take into account the pattern of errors made by an individual student over time and use this information to build a model for the education of future students. The 1990s saw computer simulation and multimedia presentations rapidly replacing older educational tools. At present, educational institutions can use multimedia and simulation environments to realise sophisticated educational methods and philosophies.

The implementation of computers in medical education has progressed at a relatively slower pace than in other arenas in the developed world. The philosophy of 'see one, do one, teach one' has been part of the medical education of residents for a long time. Undergraduate medical programmes, however, have, until recently, practised the 'chalk and talk' philosophy, supported by textbooks. Relatively new problem-based learning (PBL) curricula have changed the style of learning, particularly in North American medical schools, and we have yet to find a place for the use of computers in this new environment. At present, computer-assisted education technologies used in medicine can be divided into 6 categories:

1 PC-based interactive multimedia training systems;
2 digitally enhanced manikins;
3 virtual workbenches;
4 total immersion virtual reality (TIVR);
5 comprehensive computational models,[6] and
6 Internet-based programs for curriculum delivery and support.

At the University of British Columbia (UBC) Department of Surgery, we developed a PC-based, interactive, multimedia training system referred to as an Interactive Medical Curriculum (IMC). The IMC represents extended computer-assisted instruction (CAI) that consists of interactive tutorial patient simulation (CyberPatient), online assessment and evaluation methods, and feedback mechanisms.

Many PC-based, interactive, multimedia training systems have been developed in medicine and most of them have failed due to the high costs of development, limitations on transferability and/or compatibility, customisation to specific subjects, quality of instructional programs and, most importantly, perceptions of their effectiveness. The effectiveness of CAI has always been a subject of controversy since the advent of Skinner's teaching machines and continues to remain so.[4,5,7–9] Major factors in this controversy have been the quality of instructional programs, their availability and ease of use. The IMC developed at UBC attempted to implement the latest advances in medical practice within realistic simulated cases and step-by-step tutorials with context-sensitive help and feedback.

It is generally assumed that high quality, multimedia-based, computer-assisted training programmes will provide a more stimulating and realistic training environment that approaches the reality of the patient–doctor relationship as it happens in real life. Thus, we hypothesised that students who utilised the IMC-type computer program in their learning would outperform students who relied on the traditional textbook format of learning. In addition, variability among students in achieving instructional goals has seldom been explored. Therefore, we set out to explore the effect of CAI on groups at different levels of achievement.

METHOD

Participants

Two medical schools in Japan, Jichi Medical School near Tokyo and Kochi Medical School near Osaka, the students of which are almost identical in terms of their levels of ability, served as the study sites. Both schools run similar 6-year traditional programmes. The study was run within 1 day at each site in December 2001. The procedure at both sites was the same.

Participants were volunteers recruited from the pre-clinical years of the programmes who consented to participate in the study. Only students who reported no previous training in examining patients with complaints of abdominal pain were selected. General computer knowledge was not measured, but no problems related to this were reported in the course of the study. At Jichi Medical School, 40 students were selected and assigned randomly to 4 groups of 10 students per group. At the Kochi site, 59 students participated, in 3 groups of 15 students per group and 1 group of 14 students per group. Participants were assigned to groups at random.

Design and materials

The study employed a pretest–intervention–post-test design to compare the effects of computer-based and text-based learning. Dependent measures were the changes in performance on a multiple-choice question (MCQ) test and a procedural skills testing standardised patient (SP) encounter.

The CyberPatient^{TM} (CP) abdominal examination module includes interactive history and physical examination simulations and an online tutorial. For the purposes of the study, a text manual following the structure of the program and including the tutorial text was created.

Three conditions were set to compare computer-based and text-based learning:

1. the 'text-only' condition, where students had only the text module at their disposal;
2. the 'CyberPatient' condition, where participants were allowed to use only the CP program during the study period, and
3. the 'CP-and-text' condition, where students were allowed to use both and decided on their own what resources to use.

In order to ensure that any effects were due to the intervention, a control group was established. Control group participants were given no resources during the intervention but participated with the other students in the pre- and post-tests.

Knowledge measure

A 40-item MCQ knowledge test was developed by the experts who had developed the tutorial and the manual. The questions tested knowledge associated with conducting abdominal examinations and diagnosing conditions that present with abdominal pain. The test was blueprinted on the basis of the module's objectives and was reviewed by experts. The test was translated into Japanese by a professional interpreter. The test took 1 hour to complete and yielded percent-correct scores.

Procedural knowledge measure

Participants were required to perform 5 tasks (observation, percussion, palpation, signs, tests) on an SP. The performance of each task was observed and rated on a 3-point scale by 2 examiners. At Jichi, any discrepancies between ratings were resolved by discussion; at Kochi discrepancies between ratings were averaged. There were 10 and 15 replications of the station at Jichi and Kochi, respectively, with pairs of examiners assigned randomly to the examination rooms. Examiners were blinded to which condition each particular student had been assigned. The sum of the 5 ratings was the final score for this examination.

Background achievement

An index reflecting the achievement levels of participating students at the end of their third year was used to control for any differences in student achievement outside their performance under the 4 conditions. The grades, reported by the schools, were converted to a 3-point grade scale, where an average performance was assigned a score of 70, a good performance a score of 80, and an excellent performance a score of 85.

Evaluation survey

The evaluation survey asked students to rate several aspects of the programme, commenting on the learning materials and the study. Twelve items required students to rate different aspects of the study participation experience on a 5-point scale (where 1 indicated the lowest and 5 the highest rating). Students from the CP-and-text group were asked to compare the 2 learning resources. The last item invited students' comments on any aspect of the study and their impressions of the CP program.

Procedure

Almost identical procedures were followed at both sites, except that participants at Jichi Medical School completed the procedural knowledge test first, while participants at Kochi Medical School completed the knowledge test first. For the testing, students were divided into groups of 10 (Jichi) or 15 (Kochi), regardless of their assigned condition. Each group was led by faculty supervisors, who ensured no communication between groups for the duration of the examination. At Jichi, the groups waited in a pre-examination room until it was their turn to perform the tasks, after which they waited in a post-examination room. After all the groups had gathered in the post-examination room, the participants completed the knowledge test. Students were then regrouped according to their assigned conditions and were led by a supervisor to their respective study rooms. There they were given the study materials (or, in the case of the control group, were instructed to wait for the duration of the intervention). No cell-phones or Internet access were allowed. The intervention phase lasted 4 hours. No incidents were reported by the supervisors.

After the intervention, students were taken by the supervisors to separate locations where they completed the post-test examinations in the same order as they had the pretests. After the post-tests, participants were given a short evaluation survey to complete and were then released. Participating faculty (supervisors and examiners) completed evaluation surveys at the very end of the study.

RESULTS

Reliability of the measures was explored separately for the pre- and post-tests by site and for all participants. Reliability was acceptable (especially for the post-test measures). In addition, learning condition groups were compared on their pre-MCQ and pre-OSCE results, and on the background achievement measure. None of the comparisons reached significance. Given the high reliability and the lack of differences on the background measures (i.e. study groups were comparable), further analyses were carried out on the aggregated across-sites data and on the MCQ and OSCE indices of the intervention effect (differences between post- and pretest performance) (Table 1).

In order to explore the effects of learning condition, multivariate analysis of variance (ANOVA), with MCQ-change and OSCE-change as dependent variables and learning condition as a grouping factor, was carried out, followed by univariate tests and Scheffé posthoc multiple comparisons. The multivariate (Pillai's Trace) ($F\,[6, 190] = 22.69$, $P < 0.01$) and univariate results were significant for both measures (MCQ-change: $F\,[3, 95] = 96.31$, $P < 0.01$; OSCE-change: $F\,[3, 95] = 75.61$, $P < 0.01$). Means and standard deviations for the 2 measures are listed in Table 2. Multiple comparisons revealed that for both measures, the control group was outperformed by the other groups. For the MCQ measure, the text-based group improved significantly less than the CP and CP-and-text groups. The change in performance level of the latter groups was indistinguishable statistically. For the OSCE measure, no differences were found among the 3 study groups.

In order to explore whether students at different levels of achievement benefited from the study methods in different ways, 1-way ANOVA was carried

Table 1 Reliability (Cronbach's alpha) of pretest and post-test measures by site and for the aggregated sample

Site	Measure	Pretest	Post-test
Jichi School	Knowledge test	0.57	0.90
($n = 40$)	Performance test	0.38	0.76
Kochi School	Knowledge test	0.77	0.93
($n = 59$)	Performance test	0.58	0.89
All participants	Knowledge test	0.77	0.98
($n = 99$)	Performance test	0.49	0.83

Table 2 Means (standard deviations) for the indices of change by learning condition

Learning condition		**MCQ-change**		**OSCE-change**	
Text	(n = 24)	34.66	(11.97)	6.98	(2.93)
CP	(n = 25)	46.40	(14.61)	8.74	(2.60)
Text and CP	(n = 25)	45.06	(11.04)	8.68	(2.42)
None	(n = 25)	− 0.98	(5.51)	− 0.36	(1.90)
All participants	(n = 99)	31.25	(22.32)	6.00	(4.50)

out, with MCQ-change and OSCE-change as dependent variables and learning condition as a grouping variable, followed by Scheffé posthoc comparisons within each background achievement level. Within the lowest achievement level ('average'), students performed significantly less successfully in the text-only condition, while their performances after CP and CP-and-text learning were not distinguishable. This effect was observed for both the MCQ-change (F [2, 2] = 8.26; $P < 0.01$) and OSCE-change (F [2, 25] = 5.35; $P < 0.05$) measures.

For the medium achievement group, the learning condition was seen to have an effect on the MCQ-change measure (F [2, 26] = 5.59; $P < 0.01$). These students benefited significantly more in the CP condition. Finally, high scoring students did not seem to benefit more from any condition in particular for either the MCQ-change or OSCE-change measures. Figures 1 and 2 give a graphical representation of the described effects.

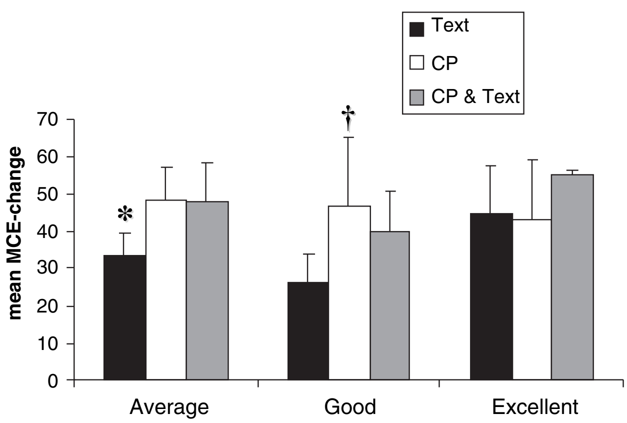

Figure 1 MCQ-change measure performance of students at different levels of achievement by study condition. * For 'average' students, the text-based learning group's change scores were significantly lower ($P < 0.01$) than those of the other 2 groups. † For 'good' students, the CP group's change scores were significantly greater ($P < 0.01$) than the change scores of the other 2 groups.

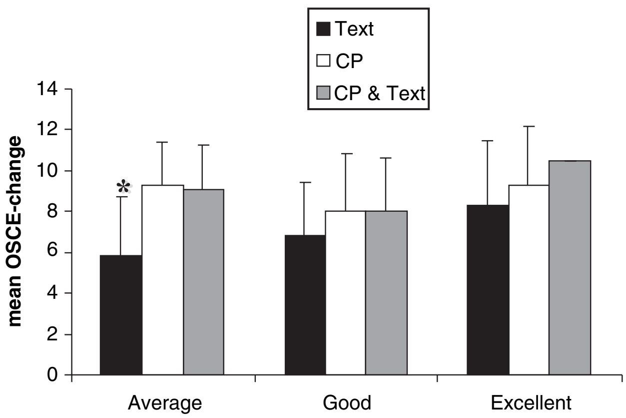

Figure 2 OSCE-change measure performance of students at different levels of achievement by study condition. * For 'average' students, the text-based learning group's change scores were significantly lower ($P < 0.01$) than those of the other 2 groups.

Correlations between achievement level and change in performance can provide further insight into how students at different levels of achievement benefited from the learning tools they were exposed to. The results of these analyses are summarised in Table 3 and Fig. 3(a–f).

Analyses of the survey questions indicated that the experience was similar for the CP and CP-and-text groups, who did not differ in their evaluations on most of the study aspects. The text-only group, in contrast, found the study much less meaningful ($P < 0.01$); students from this group reported that it was more difficult for them to concentrate ($P < 0.05$); they found the learning circumstances less comfortable and were less likely to participate in a similar study when compared to the CP-and-text group ($P < 0.05$). The results from the comparisons on the last 5 questions are displayed in Table 4. Text-only students differed significantly from the other groups in that they were less satisfied with their learning, found their learning less efficient, did not enjoy their learning, and found the material less interesting and

Table 3 Association between achievement level and performance change by learning-condition group

Learning condition		MCQ-change	OSCE-change
Text	($n = 24$)	0.39	0.35
CP	($n = 25$)	− 0.15	− 0.02
Text and CP	($n = 25$)	− 0.09	− 0.02

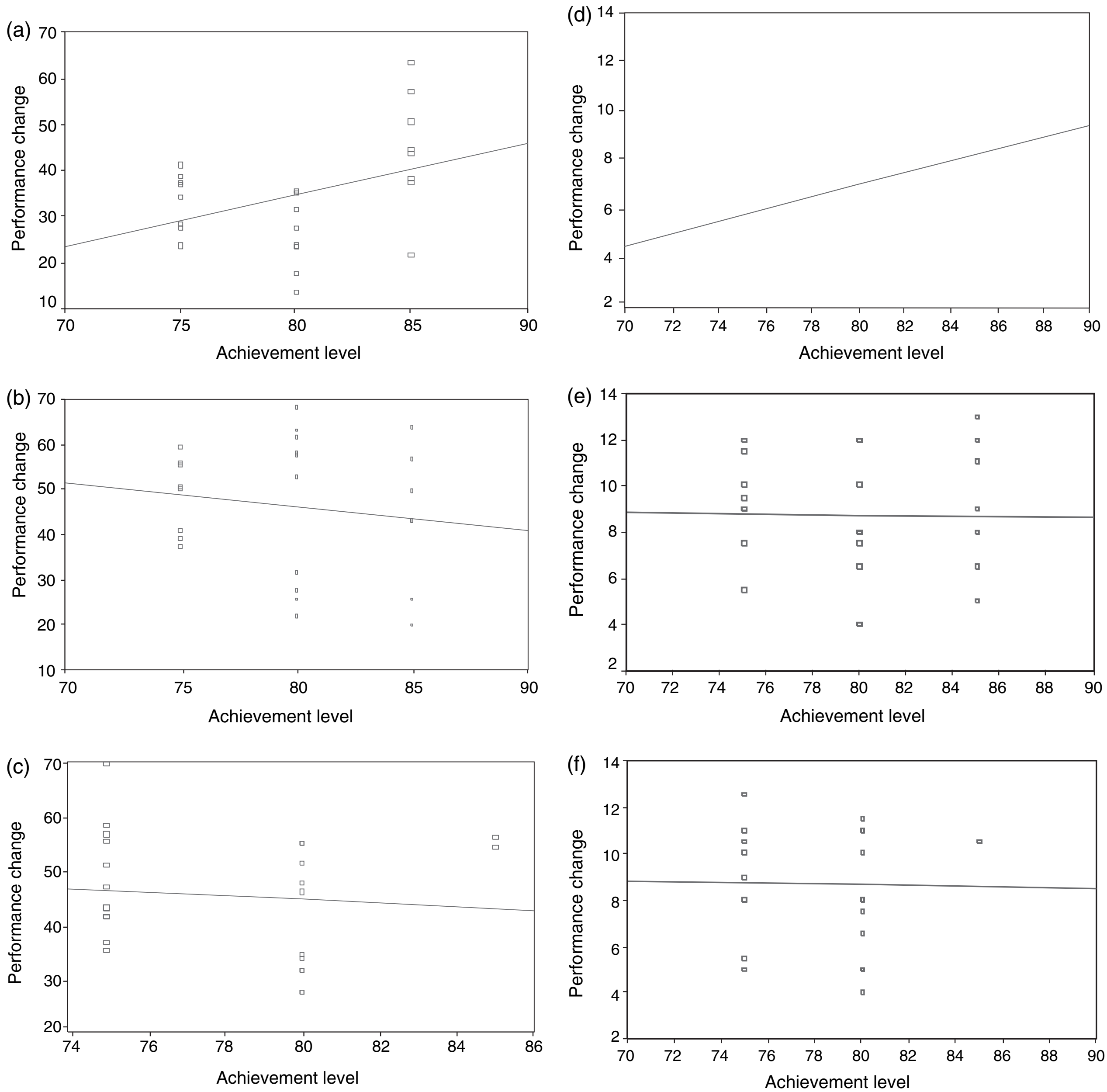

Figure 3 Achievement level and performance change by study group: (a) text-only group for MCQ measure; (b) CP group for MCQ measure; (c) CP-and-text group for MCQ measure; (d) text-only group for OSCE measure; (e) CP group for OSCE measure; (f) CP-and-text group for OSCE.

Table 4 Means (standard deviations) for the ratings on selected items from the students' survey*

Items	Text only (*n* = 24)		CP only (*n* = 25)		CP + text (*n* = 25)	
Were you satisfied with your learning?	2.42	(.93)	3.72	(0.74)	3.96	(0.89)
Was your learning efficient?	2.38	(.82)	3.52	(0.71)	3.80	(0.82)
Did you enjoy your learning?	2.96	(.95)	4.28	(0.54)	4.24	(0.78)
Was your material interesting?	3.00	(1.14)	4.32	(0.48)	4.64	(0.49)
Was your material well structured?	2.63	(1.01)	3.28	(0.79)	4.04	(0.84)
Was the CP better material then the textbook?					4.54	(0.51)

* All ratings were on a 5-point scale, where 1 indicated the lowest/weakest expression of the rated quality
CP = CyberPatient.

less well structured. Finally, the students from the CP-and-text group, when asked to compare the 2 learning sources, reported having found the CP material to be a much 'better' learning tool than the text. These students considered the program to have several advantages (e.g. its interactive nature) but also cautioned that one should not limit oneself to using the program only. Examiners expressed overall satisfaction with the program as a tool for improving instruction and assisting students' learning.

DISCUSSION

The results of this experimental protocol demonstrated that CAI significantly ($P < 0.01$) improved the theoretical knowledge of students in comparison with textbook learning; that CAI had a positive effect on the performance of students in their practical application of medical knowledge; that CAI had the most significant ($P < 0.01$) impact on students with lower overall achievement, and that CAI had the least impact on high achievers (students with high overall achievement levels).

The failure of the control group to achieve performance gains on both the MCQ and OSCE measures supports the conclusion that the observed improvement in the study groups' performance was due to the educational intervention. This finding and the lack of differences among groups on the background variables and pretest results strengthen the conclusions that can be drawn about the effects of the different study conditions on performance. For the MCQ measure, the CP study condition was associated with a performance gain significantly larger than the gain made under the text-only study condition. The differences among groups were not significant on the OSCE measure. One explanation is the relatively lower reliability of the OSCE, which results in larger error-terms for the comparisons and thus makes it more difficult to detect existing differences.

The effects of study conditions and educational environments have been variably reported and represent subjects of controversy among investigators.[10–20] Mehrabi and colleagues[10] concluded that computer-based modules employed as teaching and learning devices are superior to conventional methods, based on a study employing a teaching module with detailed clinical information, video clips and animation. Similar conclusions were reached by Seymour *et al.*[11] and Steele *et al.*[12] In contrast, Vichitvejpaisal and colleagues[13] compared CAI to traditional textbook learning and found that students in the textbook group improved their post-test scores more than those in the CAI group. Rogers and co-authors[14] also found inferior performances under CAI conditions compared to lecture and feedback seminar conditions when teaching basic surgical technical skills. The majority of publications support the notion that CAI can be as effective as traditional educational methods. The variability and controversy in results are often due to differences in study design, the quality of the programming, pedagogical values and other factors.[21–23] In the development of the software we focused on organisation, design, ease of use, quality of content, and considered appropriate pedagogical methods. These factors, in addition to the scientific design of the project, contributed to the positive results described above.

An important factor in the success or otherwise of computer-assisted learning is the attitudes of students towards CAI. Steele and colleagues[12] found that despite outcomes in favour of CAI, students expressed concerns that CAI would interfere with the traditional student–teacher encounter and relationship. The present study detected completely opposite attitudes towards CAI. The main reason for this may be that CAI should not be treated as a replacement for the traditional methods of teaching or for the teacher him or herself. As noted by Papert,[24] computers should not be considered as surrogate teachers controlling students' learning. Computers should enrich the learning environment by expanding the student's control over his or her self-learning and by providing a better learning environment as a supplement to traditional methods of learning.

In exploring how the different learning conditions affected students with different achievement levels, we found that lower achieving students learned significantly more when supported by the CP software. Average students learning under the CP condition showed significantly greater gains than those learning under the text-only condition for both the MCQ and OSCE measures. Medium achievement ('good') students benefited significantly more in the CP-only condition, as indicated by their MCQ gain scores. Finally, high scoring ('excellent') students performed equally well under all study conditions. Overall, these results indicate that including CAI enriches the study environment and helps students who do not excel under the traditional learning approaches to catch up with their high scoring peers. Analyses of the evaluation survey supported this view of the multimedia program's role: comparisons of study groups' ratings indicated that the use of the program provided more structure, kept students focused and interested, and provided a more pleasant study experience than the use of text only.

An important result in this study concerns the significant impact of CAI on low achievers. Medical students are selected from among the best of high school students who have attained adequate levels of achievement. Nevertheless, these students can attain different levels of achievement when they face the complexity of knowledge and the quantity of information taught in medical school. Only a fraction of them will fall into the highest achieving group. This group of students is not a matter for concern in pedagogical curricula. Rather, it is the group of low achieving students that causes concern in medical schools. This tends to consist of generally good students who have difficulties facing new challenges due to limitations in their learning abilities when they are confined to a single method of learning. Changing the learning environment will give them the ammunition with which to deal with new challenges and achieve more highly. This study demonstrated that an interactive, multimedia learning environment can significantly affect the achievement of students who have been portrayed as lower achievers in terms of their overall performance at medical school.

In conclusion, the study demonstrated that the inclusion of CAI results in immediate knowledge gains that surpass those of traditional, text-based methods. Future studies should address the issue of the quality of knowledge retained over longer time periods. In addition, our results suggest that CAI will be of greater help to students who do not find the traditional methods effective. Exploration of the factors behind this suggestion is a matter for future research.

CONTRIBUTORS

AKQ, GP, RC, MS and HL-G (all of UBC) were responsible for the design of the project, design and development of the software, supervision of the study in the Japanese medical schools, data analysis and composition of the manuscript.

YK, HS, KM and YM were responsible for the organisation and implementation of the study at Kochi Medical School, analysis of data sourced from Kochi Medical School and review of the manuscript.

MI, YH, MM and YK were responsible for the organisation and implementation of the study at Jichi Medical School, analysis of data sourced from Jichi Medical School and review of the manuscript.

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ETHICAL APPROVAL

Ethical approval for this study was granted by the universities at which the study took place. All participants consented to take part.

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