Influence of new educational technology on problem-based learning at Harvard Medical School

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PURPOSE Computers with 50-inch, wall-mounted plasma screens and broadband Internet access were installed in all small group tutorial rooms at Harvard Medical School. This study examines how the introduction of this educational technology impacted on the problem-based learning tutorials.

METHOD A total of 37 tutorial groups, stratified by year of student, were observed at separate timepoints (autumn 2002, spring 2003) to document the patterns of use of the technologies. Based on these observations, end-of-course surveys were developed and distributed to students and tutors. Observational field notes and open-ended survey responses were qualitatively analysed for themes.

RESULTS Using a 5-point rating scale, both students and tutors indicated that the technologies had a positive impact on their tutorials. In autumn 2002, plasma screens were used for an average of 17.8 and 22.1 minutes per 1-hour observation in Year 1 and 2 tutorials, respectively; in spring 2003, usage declined to 6.9 and 5.9 minutes, respectively. Resources utilised included Internet sites (54% total use time), PowerPoint presentations by students (22%), and course-specific postings (24%). Marked course-specific variation in usage was noted. Observational and survey data revealed that the technologies interrupted the flow of tutorial discussion. Students and tutors expressed concerns that the plasma screens might be altering the process of problem solving in the tutorials.

CONCLUSIONS Both students and tutors reported that the introduction of computers and wall-mounted plasma screens had impacted positively on tutorials. Questions were raised as to how this technology might alter tutorial dynamics. Further research will be needed to investigate these pedagogical concerns.

KEYWORDS education, medical, undergraduate/ *methods; problem-based learning/ *methods; computers/ *utilisation; technology/ *education; attitude of health personnel; United States.

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INTRODUCTION

A critical question in medical education is how best to incorporate emerging technologies into medical students' education. This question is not new. A core component of the 'New Pathway' reforms at Harvard Medical School (HMS) in the 1980s was to ensure that medical students developed competency in the use of 'information-processing devices' in order to facilitate patient care.[1] At that time, HMS provided students with computer-aided instruction on an *ad hoc* basis, but those efforts were felt to be of limited educational impact due to the dearth of available software[2] and the poor integration of such applications into the students' curriculum.[3]

Over the last 2 decades, educational technology has evolved dramatically and medical schools have made enormous institutional investment to keep pace with these trends. Local intranets have been developed to link faculty and students to a growing menu of technology-based services, including access to vast digital libraries.[4] Home-grown or commercial web-based platforms, such as Blackboard™, are being used to streamline course administration. Educational programmes and resources continue to grow rapidly in number and quality as faculty and

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Overview

What is already known on this subject

Little research has been conducted to assess the impact of educational technologies on the process of problem-based learning.

What this study adds

Utilising both qualitative and quantitative research methods in a 2-pronged prospective cohort evaluation, this study critically analysed how small group tutorials at Harvard Medical School were impacted by the installation of a computer with a 50-inch, wall-mounted plasma screen and broadband Internet access in each tutorial room.

Suggestions for further research

Further investigation is indicated to optimise the utility of these technologies and to assess in more detail how they might alter students' problem solving processes.

students become increasingly comfortable with the use and development of web-based materials.[5,6]

One crucial question remains: what role should such advances in educational technology play within the realm of problem-based learning (PBL) tutorials? In order to bring web-based resources directly to the tutorial room, HMS installed a computer with broadband Internet access and a 50-inch, wall-mounted plasma screen into each small group tutorial room (Fig. 1). Students and tutors are now able to access digitised case images, search the digital library or PubMed™, and explore the Internet for relevant information. While the technology is state-of-the-art and the institutional investment is substantial, the research question emerges as to how this technology impacts on PBL tutorials.

METHODS

Study design

This study used a 2-stage prospective cohort evaluation utilising both qualitative and quantitative research methods. Data were collected through ethnographic observation and surveys.

Study participants

All 342 students in HMS Year 1 and 2 classes during the 2002–03 academic year were asked to participate in the study. All of them agreed to be observed and survey response rates ranged from 80% to 98%. These particular cohorts of students were selected because it is during these 2 pre-clinical years that PBL in small groups forms a core component of the students' curriculum. The courses observed were purposefully selected to assess both the immediate and delayed impact of the new technologies. In the autumn, they included the Year 1 module on the human body (anatomy/histology; 8 weeks, 23 tutorial groups) and the Year 2 module on the human nervous system and behaviour module (8 weeks, 24 tutorial groups). In the spring, they included the Year 1 module on pharmacology (4 weeks, 24 tutorial groups) and the Year 2 module on human gastrointestinal pathophysiology (3 weeks, 24 tutorial groups). The average number of students in each tutorial group was 8. All 98 tutors on these courses were asked to participate in the study. Most tutorial groups (92 of the 95) had a single tutor, and the remaining 3 had co-tutors.

Data collection

A total of 37 tutorial groups, stratified by year of student, were observed at separate timepoints by the authors to document use patterns of the new technologies. Following an ethnographic approach,[7] field notes were taken during each observation. Based on those observations, survey questions were developed and field-tested on a 9-member student focus group. The questions were then distributed to all students as part of an intranet web-based, end-of-course evaluation instrument. Separate paper-based surveys were distributed to all tutors at the end of each course. The tutors' survey contained the questions that were on the students' survey. In addition, we asked the tutors whether they set up tutorial guidelines for plasma screen usage and what suggestions they had for improving its use. Students and tutors were asked to rank on a 5-point scale and comment upon the impact the computers and wall-mounted plasma screens had on their tutorials.

Data analysis

Observational field notes and open-ended survey responses were qualitatively analysed according to

Figure 1 A 50-inch, wall-mounted plasma screen in a small group tutorial room. (© President and Fellows of HMS Media Services 2003).

Miles and Huberman methodologies.[8] Themes emerged from open coding and frequency counts. The Mann–Whitney *U*-test was utilised for comparative analysis of survey ratings.

RESULTS

Tutorial observations

In this 2-stage study design, tutorial sessions were observed for a total of 33.9 hours (55-minute average duration of observation). In autumn 2002, immediately after the plasma screens and computers had been installed, the new technologies were utilised for an average of 17.8 and 22.1 minutes per 1-hour of tutorial by Year 1 and 2 students, respectively (Table 1). In spring 2003, average use per tutorial hour declined to 6.9 and 5.9 minutes, respectively.

Observational data showed a considerable degree of course-specific variation in how the technology was utilised. The use of the plasma screens to display course-specific material peaked with an average of 10.3 minutes per 1-hour of tutorial in the human body course (Year 1 students, autumn 2002). Over the years, this course has developed an extensive array of case-related, digitised anatomical and radiological images that were made available over the medical school's intranet. Year 2 students on the human nervous system and behaviour course were unique in their frequent delivery of PowerPoint presentations to their fellow tutorial members via the plasma screens (Table 1). These presentations fulfilled a course requirement that selected students give a brief summary to their group at the end of each week's case.

Observational data determined that searching the Internet for case-related material was a frequent use of the plasma screens (Table 1). When students in a number of tutorial groups were not familiar with a term or concept presented in their tutorial case, the group or an individual initiated a search of the Internet using the Google™ search engine. Students also were observed to utilise online references such as UpToDate™ and Harrison's Online™, which are available through the medical school's digital library. The resulting materials could then be displayed on the plasma screen, where the group as a whole could see the information and discuss its relevance to the case. Less frequently, students were observed to use the plasma screens and computers to look up relevant web-based references that they had located prior to the tutorial.

The use of the plasma screens was occasionally observed to interrupt or disrupt the flow of the tutorial discussion. An interruption/disruption was defined as 'a student's or tutor's use of the plasma screen causing 2 or more students to become disengaged/distracted from the group discussion.' On several occasions, the entire discussion was halted while a student performed a Google search on the

Table 1 Summary of observational data from tutorials

	Autumn 2002		Spring 2003	
Student year	**Human Body Year 1**	**Human Nervous System and Behaviour Year 2**	**Pharmacology Year 1**	**Gastrointestinal Pathophysiology Year 2**
Total hours of tutorial observed	9.7 hours	11.0 hours	7.0 hours	6.3 hours
Plasma screen use*	17.8 minutes (0.0–50.7)	22.1 minutes (0.0–44.5)	6.9 minutes (0.0–18.0)	5.9 minutes (0.0–40.0)
Intranet course material use*	10.3 minutes (0.0–50.1)	0.0 minutes	1.0 minutes (0.0–4.0)	N/A
Internet use*	7.6 minutes (0.0–28.0)	11.9 minutes (0.0–45.3)	5.9 minutes (0.0–18.0)	N/A
PowerPoint use*	0.0 minutes	10.2 minutes (0.0–32.0)	0.0 minutes	0.0 minutes
No. of disruptions of tutorial process by screen use*	2.2 (0.0–6.2)	1.0 (0.0–4.0)	1.1 (0.0–4.0)	N/A
Duration of disruption*	5.0 minutes (0.0–21.0)	3.4 minutes (0.0–15.0)	2.9 minutes (0.0–11.0)	N/A
Chalkboard use*	10.8 minutes (0.0–34.0)	14.8 minutes (0.0–60.0)	12.7 minutes (0.0–20.0)	8.8 minutes (0.0–20.0)

* Average per hour of tutorial.
(Ranges listed in parentheses)

Internet. On average, 1.0–2.2 of these disruptions were noted per hour of tutorial, with the duration of the disruption lasting from 2.9 to 5.0 minutes (Table 1).

Chalkboards – the traditional visual medium – were often utilised by the tutorial groups, with an average use of 8.8–14.8 minutes per 1-hour of tutorial (Table 1). Increased plasma screen use did not correlate with decreased chalkboard use.

Survey responses: quantitative

Survey response rates were high among all groups, ranging from 80% to 98% among students and from 77% to 92% among tutors (Table 2).

All groups reported that the plasma screens and computers had a positive impact on their tutorials (Table 2). In autumn 2002, students in Years 1 and 2 were significantly more likely than their tutors to

Table 2 Medical students' and tutors' responses to the following question: Please rate how you feel the introduction of computers and wall-mounted plasma screens has impacted your tutorial? (1 = very positive impact, 5 = very negative impact)

	Autumn 2002				Spring 2003			
	Human Body Year 1		**Human Nervous System and Behaviour Year 2**		**Pharmacology Year 1**		**Gastrointestinal Pathophysiology Year 2**	
	Students	**Tutors**	**Students**	**Tutors**	**Students**	**Tutors**	**Students**	**Tutors**
Mean	1.62	2.05	1.64	2.08	1.88	2.21	1.94	2.32
Median	1.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00
SD	0.78	0.91	0.91	0.93	0.88	0.97	0.88	0.95
Survey response rate	98% (168/171)	86% (19/22)	98% (167/171)	92% (24/26)	80% (136/171)	77% (20/26)	82% (141/171)	96% (23/24)

report a positive impact by the introduction of plasma screens and computers ($P = 0.032$ and $P = 0.010$, respectively (Fig. 2). This student/tutor difference was no longer statistically significant by the spring of 2003. In spring 2003, the ratings of both Year 1 and Year 2 students were significantly less favourable compared to their average ratings in autumn 2002 ($P = 0.008$ and $P < 0.001$, respectively). Even so, their average ratings remained well within the 'positive impact' range (Fig. 2). Although the Year 2 students had spent their previous year in tutorial groups without the plasma screens and computers, there was no statistically significant difference between the ratings of Year 1 and 2 students (data not shown).

Survey responses: qualitative

Themes were identified from recurring concepts within survey responses and notes from field observations. Students' and tutors' responses to the surveys' open-ended questions were subsequently coded for themes according to Miles and Huberman.[8] Inter-coder agreement ranged from 88% to 95%, and code–recode agreement was 89–100%.

Information access and multimedia capabilities

Both students and tutors most commonly reported that the multimedia capabilities of the plasma screens and their ability to provide immediate access to information had a positive impact on their tutorials. One tutor on the human nervous system and behaviour course stated:

> '[The plasma screens] allowed students to use interactive learning tools, animation, and multimedia databases to better problem-solve and enhance their use of new information relating to important issues in the case. Overall, the plasma screen effectively linked learning content with group discussion.'

A pharmacology tutor also believed that the increased speed of information access facilitated the problem-solving process:

> 'Students are able to access information faster than from the available classroom textbooks; certainly more resources [are] available to access on the Internet and digital library; having more definitions and resources at their fingertips seemed to allow the students more time to problem solve and hypothesise.'

The multimedia capabilities of the plasma screens were cited by many students and tutors as being of great assistance in learning basic human anatomy or neuroanatomy due to their ability to project

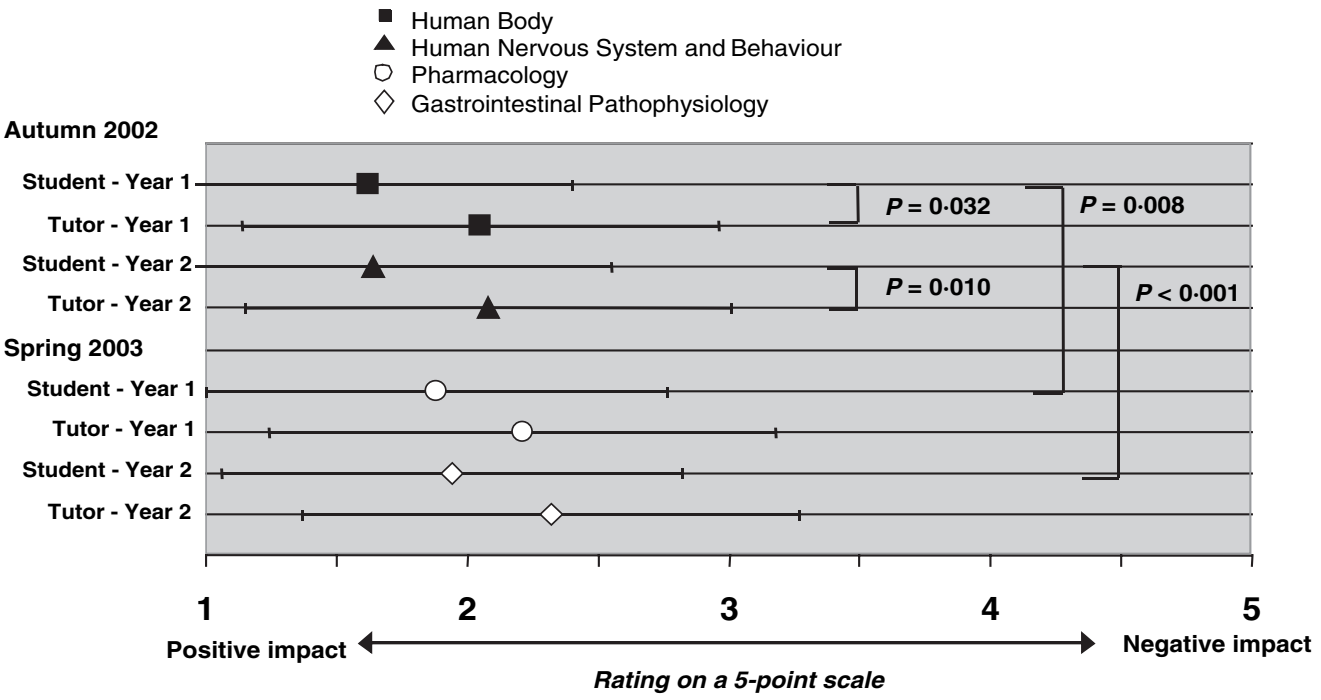

Figure 2 Medical students' and tutors' mean responses to the following question: Please rate how you feel the introduction of computers and wall-mounted plasma screens has impacted your tutorial? (1 = very positive impact, 5 = very negative impact.) Bars indicate standard deviation. The statistically significant differences between cohorts are indicated.

anatomical or radiological images for the entire tutorial group to visualise and discuss. One human body tutor highlighted this by saying:

> 'Anatomy is a visual subject and the ability to have large images for the cases is extremely valuable. With the plasma screens the images can become the focus of the tutorial rather than a distraction.'

Interruption and distraction

Multiple students and tutors remarked that use of the plasma screens had the potential to distract the students and interrupt the flow of the tutorial discussion. A Year 1 tutor said:

> 'Sometimes it seemed that the computer was a distraction from group discussions. One person would often be searching the web while everyone else was having a discussion. Not only was the student using the computer left out of the discussion, but the students having the discussion were also often distracted by what was happening on the plasma screen.'

Tutors cited the potential for interruption/distraction in their surveys much more frequently than did students (13–37% versus 2–11%, respectively). One tutor reported that it was challenging to shift the students' attention away from the technology once the screen had been utilised:

> 'Sometimes [we] could not find the information we needed or there was too much information to sift through to get an answer. Students would become fixated on the screen and it became very difficult to turn their attention to other issues even though 1 student (out of 8) would keep looking for it.'

Reliability of online information

Several tutors questioned the reliability of the online resources utilised by the students. One pharmacology tutor stated:

> 'The sources of information were not always authoritative and it often required wading through extraneous, irrelevant or even incorrect information.'

One Year 1 student recommended that:

> '…students [should] only use reputable, scientific sources and not just ''Google'' everything.'

Changes to the process of problem-based learning

A minority of tutors raised the concern that using the plasma screens to access information on the Internet altered the methods and rigour with which students looked for new information to solve problems. One human body tutor explained:

> 'If they couldn't find it in the web, they pretty much would ''close the book'' on the topic. Looking things up in the reference books provided for the tutorial group was not instinctive. Most of the time, I had to suggest it.'

The ability to find immediate answers to questions on the Internet during tutorial was cited by several students as a positive aspect of the plasma screens and computers. In a representative comment, a Year 2 student said:

> '[It is] very nice to be able to look stuff up during tutorial rather than making lists of stuff to look up and bring back.'

Concerns were raised by multiple tutors that this immediate access to information through the Internet undermined critical thinking on the part of the students. One pharmacology tutor stated that the presence of the plasma screens:

> '...facilitated the students' search for answers rather than the development of problem-solving skills on their own. [They also] prevented students from thinking through a problem when the answer could be accessed online.'

These concerns were mirrored in several of the students' survey responses. The following comment from a Year 1 student is representative:

> '…I usually end up feeling that people rely on the web as a way to avoid having to think critically about the tutorial cases. Yes, the web can provide useful information regarding clinical details with which we are unfamiliar... The goal [of tutorial] is to learn how to think about a problem, generate hypotheses, explore the validity of hypotheses, and find the appropriate material and information to confirm or deny those ideas. If used responsibly, the plasma screens can be useful in the collection of information aspect of tutorial. But there are few things in tutorial that frustrate me more than the immediate rush to http://www.google.com to see if we can find a disease that matches our list of

symptoms. I think this reflects a greater misunderstanding of the purpose of tutorial.'

DISCUSSION

As early as 1979, Daniel Tosteson, dean of Harvard Medical School (1977–97), proposed that the use of 'information-processing devices'[1] be developed as a core component of the medical school curriculum:

> 'We do little in our schools to help people who will be practising medicine during the next 30 years to become familiar, comfortable and capable with these new tools. Medical education should do more to prepare doctors to use information-processing devices.'[1]

While computing has evolved greatly since Tosteson's statement, questions remain as to how best to incorporate these technologies into medical students' education. The introduction of computers with wall-mounted plasma screens and broadband Internet access into PBL tutorials provides a model by which these educational technologies can be delivered to students and displayed in a manner that invites group discussion. The data from this study indicate that both tutors and students felt that these technologies made a positive impact on the PBL tutorials. At the same time, the data raise several important pedagogical issues. As the number and quality of technology-based resources grow, the utility of the plasma screens in integrating these educational materials into small group tutorials is likely to continue to increase. For instance, a pilot project is currently underway at HMS to develop video-based tutorial cases in which history taking, physical examination and patient–doctor interaction can be displayed on plasma screens and used as a stimulus for student discussion.[9]

Several important pedagogical issues were identified in this study. A central tenet of PBL is that students should learn how to think through a clinical or basic science problem.[10] 'If you visit a tutorial group on the first day of consideration of a new case, the air is filled with unlikely, scientifically implausible, even preposterous hypotheses,' writes Daniel Federman.[11] After creating hypotheses and elaborating upon explanatory models, students then traditionally generate an agenda of the topics that they will investigate on their own prior to the next tutorial.[12] Our data suggest that the plasma screens were being utilised in an attempt to obtain immediate 'answers' to case scenarios via Internet searches. While this tactic may speed the resolution of the case, it has the potential to circumvent the hypothesis-generation and knowledge-elaboration processes that are fundamental to effective PBL.[9] In addition, the 'data-gathering phase' of PBL, which traditionally has occurred outside the tutorial, can now become a major activity within the tutorial itself through the use of Internet searches on the plasma screens. This can interrupt the flow of tutorial discussion and may undermine the stimulus for student-directed learning on these topics outside of tutorial.

Several tutors questioned whether the process of accessing and presenting information on the plasma screens reduced their students' depth of understanding of the subject materials. This study was not designed to answer that difficult question, but the active incorporation of the displayed materials into the group discussion should improve the students' ability to digest and internalise the content material. Concerns were also raised as to the reliability and validity of the information accessed on the Internet. It is crucial that the ability to access information via the plasma screens be coupled with the ability to critically evaluate the content validity of web-based resources. This 'information literacy' of web-based content may need to be an explicit part of the tutorial curriculum.[13]

The plasma screens' clarity and large size make them an effective means by which to share digitised radiographs and web-based resources with the entire tutorial group. However, if 1 student is using the plasma screen, the screen's large size makes it very easy for other members of the tutorial group to be distracted and the flow of discussion interrupted. The establishment of specific guidelines that limit use by individual students may help reduce this tendency to distract.

The reason for the decline in plasma screen use observed over the year (autumn versus spring; Table 1) is not clear, but may be due to course-specific variations or to a reduction in the novelty of the screens over time. Given that neither students nor faculty members had any prior experience with plasma screens, it can be expected that their use of the technology will shift over time as they learn to incorporate this tool into PBL. Further study of these variations is warranted.

There are several limitations to this study. As the impact of these technologies was assessed at only 1 medical school, the ability to generalise the results

to other institutions and to other forms of PBL may be limited. Our 2-stage analysis focused on the screens' first year of use in order to better assess any immediate versus delayed changes in tutorial processes, but this relatively short duration of study may not capture longer term utilisation patterns.

While the ability of computers and plasma screens to access and display information is impressive, we must proceed with care because information does not necessarily equal knowledge.[14] We need to take advantage of the great potential of educational technology, but it is important that we do not let it undermine the core components of effective pedagogy. The results of this study will be utilised in tutor faculty development and training sessions so that these new technologies can be used for the greatest educational benefit.

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REFERENCES

1 Tosteson DC. Learning in medicine. *N Engl J Med* 1979;**301**:690–4.

2 Silver MT. The student experience. In: Tosteson DC, Adelsten SJ, Carver ST, eds. *New Pathways to Medical Education: Learning to Learn at Harvard Medical School.* Cambridge, Massachusetts: Harvard University Press 1994.

3 Barnett GO. Information technology. In: Tosteson DC, Adelsten SJ, Carver ST, eds. *New Pathways to Medical Education: Learning to Learn at Harvard Medical School.* Cambridge, Massachusetts: Harvard University Press 1994.

4 Lee MY, Albright SA, Alkasab T, Damassa DA, Wang PJ, Eaton EK. Tufts Health Sciences Database: lessons, issues and opportunities. *Acad Med* 2003;**78**: 254–64.

5 Fleiszer DM, Posel NH. Development of an undergraduate medical curriculum: the McGill experience. *Acad Med* 2003;**78**:265–9.

6 Candler CS, Uijtdehaage SH, Dennis SE. Introducing HEAL: the Health Education Assets Library. *Acad Med* 2003;**78**:249–53.

7 Emerson R, Fretz R, Shaw C. *Writing Ethnographic Field Notes.* Chicago: University of Chicago Press 1995.

8 Miles MB, Huberman AM. *Qualitative Data Analysis: an Expanded Sourcebook.* 2nd edn. Thousand Oaks, California: Sage Publications 1994.

9 McMahon GT, Hafler JP, Dluhy RG. *Development and Implementation of the VISUAL Project (Video for Structured Understanding and Learning), Harvard.* Boston: Macy Institute Program for Physician Educators 2003.

10 Schmidt HG. The rationale behind problem-based learning. In: Schmidt HG, Lipkin M, de Vries MW, Greep JM, eds. *New Directions in Medical Education: Problem-based Learning and Community-oriented Medical Education.* New York: Springer-Verlag 1990.

11 Federman DD. Little-heralded advantages of problem-based learning. *Acad Med* 1999;**74**:93–4.

12 Moore GT. The first curriculum: content and process. In: Tosteson DC, Adelsten SJ, Carver ST, eds. *New Pathways to Medical Education: Learning to Learn at Harvard Medical School.* Cambridge, Massachusetts: Harvard University Press 1994.

13 Roth L. Educating the cut-and-paste generation. *Library J* 1999;**124**:42–4.

14 http://www.technorealism.org. [Accessed June 4, 2003.]

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