Int. J. Engng Ed. Vol. 21, No. 6, pp. 1168–1176, 2005
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Implementing and Assessing Computer-based Active Learning Materials in Introductory Thermodynamics*

EDWARD E. ANDERSON, ROMAN TARABAN
Texas Tech University, Lubbock, TX 79409, USA. E-mail: ed.anderson@ttu.edu

M. P. SHARMA
Department of Chemical Engineering, University of Wyoming, Laramie, WY 82071-3295, USA

Students learn and retain more as they become increasingly engaged with instructional materials. We describe active-learning teaching methods that we used to develop computer-based instruction modules for introductory thermodynamics. These methods, which can be generalized to other topics in engineering, include the use of interactive exercises, immediate feedback, graphical modeling, physical world simulation, and exploration. Ongoing assessment of the effectiveness of these materials has been carried out in parallel with development, in part, to assure that students have access to the required technology and sufficient time outside of class to use the materials. The assessment data include behavioral and cognitive variables that were used to examine the usability and impact of the computer modules.

INTRODUCTION

IT IS WELL KNOWN that students learn and retain more as they become more engaged with instructional materials. Reisman and Carr [1] concluded that students learn 20% of the material taught by hearing, 40% by seeing and hearing, and 75% by seeing, hearing, and doing. Well-designed computer-based instruction (CBI) modules offer the possibility of achieving the 75% goal through multimedia presentation formats and student interactions. Attitudes towards interactive materials have been positive. Renshaw *et al.* [2], for instance, stated that 'students unanimously preferred modules that incorporated animations and interactive design tools'. Others [2–7] have reported similar findings in several engineering fields and topics. We believe that a current challenge in engineering education is to develop active learning exercises that are simple, relate to the learner's experience level, and that can be incorporated into and synchronized with other teaching pedagogies. The materials need to be structured so that learners can proceed at their own pace, receive appropriate feedback and coaching, and can review as often as necessary to achieve mastery.

A related challenge is to assure that instructional materials are useable, and that they make a difference in learning. There are several reasons why assessment must be part of the development of new materials and pedagogical methods. As teachers are well aware, there are broad differences in background knowledge, ability, and interests in the students who register for their courses. Teachers, as well, incorporate a broad range of practices into course development and delivery. Finally, there is no 'science' of teaching that can guarantee definite results. Therefore, it is imprudent to assume that instructional modules, labs, and other materials will help students learn simply because the teacher has made the materials available to students.

The first part of this paper presents and discusses several kinds of interactions and exercises that have been integrated with a complete CBI system and textbook [8]. These include:

- content pages with narrative voice-overs and clickable figures and animations;
- interactive questions;
- short-response interactions;
- coaching interactions;
- and experimental simulations.

The examples that are presented were taken from the Introduction to Thermodynamics course that is taught to almost every engineering and technology student. This course is particularly challenging because it is normally taught without a laboratory experience. It also contains many physical concepts that are unfamiliar to students. Most of these are easily observed with simple experiments that can be simulated by a computer. Therefore, this course is well suited to the use of active learning techniques that are integrated with the static elements of the course:

- Basic properties: pressure, temperature, density, internal energy, entropy, and enthalpy.

* Accepted 22 July 2004.

- Equations of state, specific heats, phase conversion, and tables of properties.
- Thermodynamic systems, process, work, and heat concepts.
- Conservation of energy for closed, steady-state, and transient systems.
- Second law of thermodynamics, entropy, and the consequences of the second law.
- Exergy and entropy concepts, and balances.
- Application of the thermodynamic principles to basic reciprocating-piston engines, gas turbines, electrical power generation, refrigerators, and heat pumps.

The second part of the paper outlines the multi-faceted approach that we are using to assess the usability, quality and impact of these materials on student learning at Texas Tech University (TTU) and the University of Wyoming (UWyo). These include:

- assessment of the technological needs and challenges posed to students using the materials;
- estimating the amount of time students spend on the supplemental materials in the context of the time spent on the course in general;
- detailed analysis of how students navigate through the computer-based materials;
- detailed analysis of how students think about the concepts and the media;
- and the impact of using these materials on mastery of the course material.

Measurement of the impact of CBI on knowledge gained provides a gauge that developers can use to improve or discard marginal exercises and retain successful ones. Measuring the changes in the knowledge states of students should ultimately allow us to assist those who begin a course with varying and perhaps inadequate knowledge backgrounds, who interrupt or modify course sequences, or who short-circuit or perform poorly in prerequisite courses. Finally, it is important to assist students in the transition from low-risk, low-investment learners to self-paced, lifelong learners. To achieve this, it is necessary to develop the means and methods to measure these changes and to tailor learning materials to contribute to the accomplishment of this goal.

ACTIVE LEARNING EXAMPLES

Content pages with narrative voice-overs and clickable figures and animations

Approximately two-thirds of the instructional material consists of text and graphics pages with audio voice-overs. These are designed to present the material in a succinct and compact form for the learner. A typical screen of this type is presented in Fig. 1.

Many of these screens contain cursor-over pop-ups to display additional graphics or information about the topic. For example, dragging the cursor over the turbine building of Fig. 1 causes an interior view of the turbine floor to appear. All screens contain an 'additional information' button which when clicked causes additional textual information to appear. The purpose of this feature is to address the learning needs of those students who need to explore the topic deeper than is done by the initial narrative and displayed information. Many of these pop-ups also contain links to additional web pages that go even deeper into the topic. This layering of depth of topic coverage is provided to allow the users to explore each topic to the depth they feel is sufficient to reach their learning goals.

Interactive questions

The simplest active learning exercise to implement in a CBI module is the interactive question

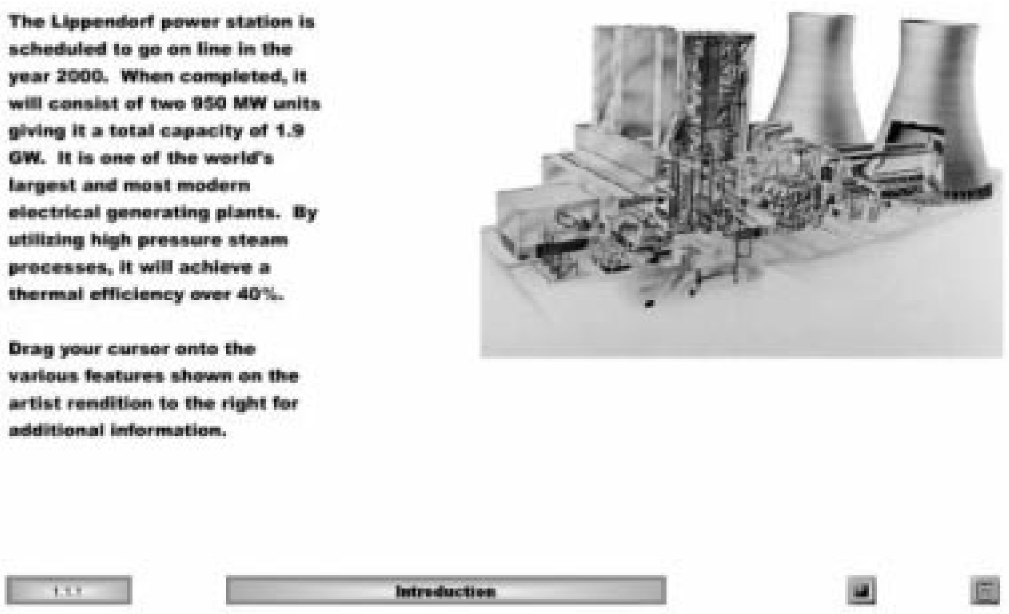

Fig. 1. Typical content page.

that usually takes the form of a multiple-choice or short-answer question. Both of these formats are easily graded and immediate feedback based upon the user's answer is readily programmed into the module. They also serve to interrupt passive learning, which occurs as students read static text or listen to lectures. This interruption resets the student learning effectiveness to a higher level [9, 10] thereby improving mastery and retention of the material.

An example of this type of active exercise is shown in Figure 2. This particular exercise was taken from one of the modules developed for this project. This exercise is basically a multiple-choice question which is to be answered by dragging the equation for the volume of an object onto the correct object, which in this example is the triangular prism. This exercise appears following a brief lecture on extensive and intensive properties, and the system volume property. Its purpose is twofold: to reinforce the concept of volume as an extensive property and to remind students that they are responsible for knowledge acquired in previous courses. If the student drags the equation onto the wrong figure, the equation returns to its original position as a visual means of coaching the student.

This particular example follows three screens of popup text synchronized with an audio voice-over. These screens are included with the interactive version of this paper. Although the placing of exercises such as this is subject to the material being taught and the objectives of that material, their purpose is defeated if they are too infrequent. It is suggested that they be placed no more than 2–4 screens apart to keep students actively engaged with the material.

Short response interactions

Short-response interactions are also known as short-answer questions when the student enters text to answer a question. Engineering and the physical sciences often don't use text as a short response, but rather use digits, symbols, or equations for the short answer. These forms of input can be cumbersome in view of the limitations of the computer keyboard. An alternative means of executing a short response input is presented in Fig. 3. This exercise begins by presenting the textual material shown on the left-hand side of the screen, which summarizes the definition of pressure. The user is then asked to determine the amount of weight that must be placed upon the piston to generate a certain pressure in the piston-cylinder contents. The target pressure is a randomly generated number and users are expected to do an off-line calculation to determine the required weight. The user then proceeds to drag weights onto the piston until the proper amount of weight has been added to achieve the desired pressure. Each time a new weight is added to the piston, the pressure gauge indicates the new pressure.

This rather simple exercise demonstrates many of the features found in well-designed CBI learning modules. It states the objective, engages the user, allows the user to explore and discover, correlates the information with other sources, provides feedback, may require iteration, and takes advantage of the features found in CBI that are not available in static media. As with the proceeding example, this exercise follows a brief lecture on pressure, which is included with the interactive version of this paper.

Coaching interactions

Student coaching interactions actively engage students in the learning process and allow them to discover knowledge and thereby retain that knowledge. Although coaching is most commonly used with exercises that provide feedback when the student completes the exercise, it can be accomplished in other ways.

An example of an alternate application of coaching in this project is shown in Fig. 4. This application encourages the student to explore the various terms of the equation on the right-hand side of the screen by dragging the cursor over the

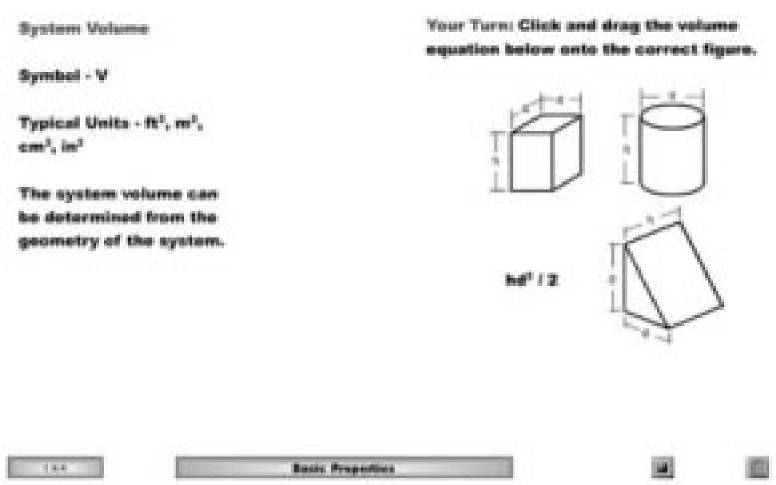

Fig. 2. Multiple choice interaction example.

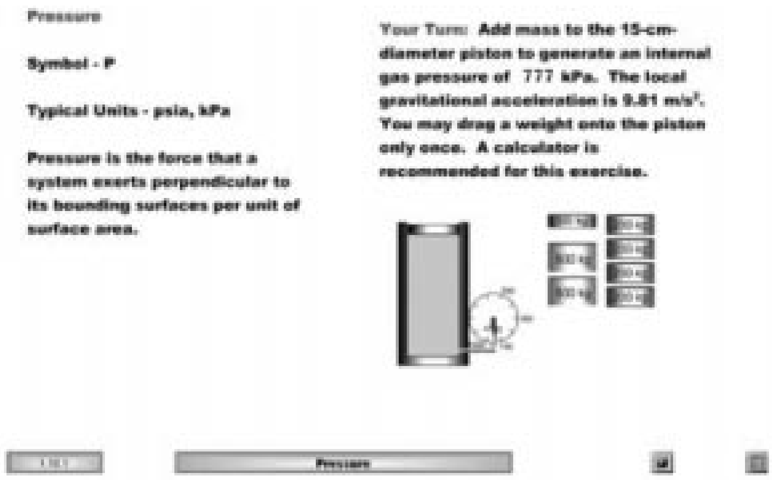

Fig. 3. Short response interaction example.

terms. Once the cursor is over a specific equation term, a coaching message, like that shown in Fig. 4, appears. The first law of thermodynamics has been thoroughly discussed using pop-up text synchronized with voice-overs in the screens preceding this exercise, as demonstrated in the interactive form of this paper. These coaching messages then serve to reinforce the previous presentations.

In addition to repeating the information and reinforcing it, these coaching messages serve to engage the visual learner rather than the audio learner who was engaged during the preceding screens. One of the principal benefits of CBI is that it can accommodate many different learning styles. Instructional developers should always take advantage of this benefit and use it to actively engage the various learning styles.

Experimental simulations

Another method of actively engaging students with the material is to have them perform simulations of physical experiments. The simulation shown in Figure 5 demonstrates liquid-vapor phase conversion as a substance undergoes a constant pressure heating process. During this conversion experiment, temperature-time and volume-time data are recorded and plotted. The initial screen for this simulation is presented in Fig. 5.

The experiment is performed in the piston-cylinder device shown in Fig. 5. As heat is transferred from the flames to the water in the piston-cylinder device, students can observe the relative amount of liquid and vapor, the total volume of the liquid-vapor mixture, the temperature of this mixture, and a plot recording the system volume as time passes. This plot is synchronized with the location of the piston. Students run this experiment at three different pressures by clicking on the appropriate buttons. The final results of this experiment are shown in the data plot of Fig. 5.

Although students in introductory thermodynamics courses have a general concept of phases—basically, solid, liquid, and gaseous—they don't have the depth of understanding of phases required for thermodynamic analysis. Phase conversion and the effect of the pressure upon the conversion is a difficult concept to grasp from static descriptive materials. Historically, this concept was experienced in laboratory experiments

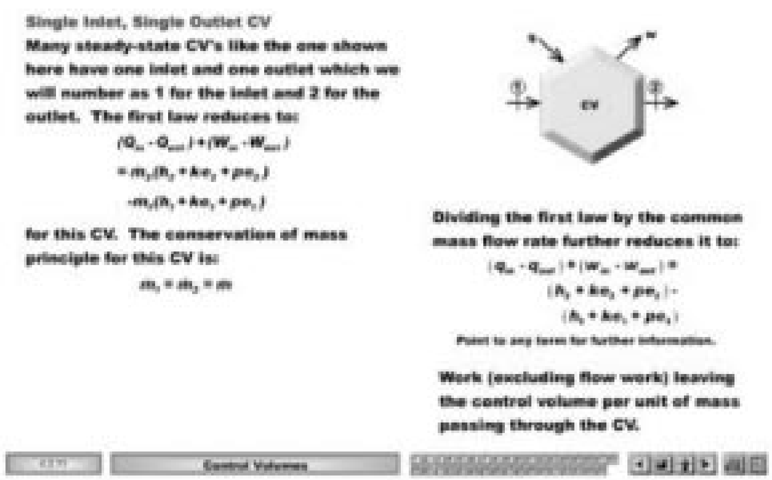

Fig. 4. Coaching interaction example.

or physical demonstrations, typically in chemistry or physics lectures. For the most part, this is no longer done.

This simulation may actually be preferred to a similar physical experiment. In the laboratory, it is difficult to physically create equilibrium, heat transfer and transient effects make it difficult to observe the points of volume-time slope discontinuity, transparent cylinders typically fog up, thereby limiting the visibility of the process, and students lose learning time as they are trained in the operation of the equipment.

The screen immediately following Fig. 5 is shown in Fig. 6. The purpose of this screen is to begin the development of the concept of phase diagrams. The concept of a saturation line and of areas bounded by saturation lines representing the states at which different phases of the fluid occur are demonstrated in this screen. An audio voice-over that presents an additional explanation of the concepts shown in this figure accompanies this screen.

The volume-time behavior of this experiment is the second in the set of experiments performed by the student. The results of both experiments are then used to develop the pressure-specific volume state diagram by cross-plotting the results. Student comments have indicated that they have a better appreciation of the pressure-specific volume-state diagram and its application to state determination and analysis as a result of these virtual experiments.

ASSESSMENT METHODS

Availability and usability of technology

As we began introducing the CBI materials into the thermodynamics courses in the form of a CD-ROM, we addressed student preparedness for these materials through the use of questionnaires [11]. A large percentage of the students indicated that they owned computers with Internet access (TTU = 85% and UWyo = 78%). An even larger percentage claimed to own computers with CD-ROM drives (TTU = 92% and UWyo = 87%). When asked to rate their computer skills, many, but not all students, rated their skills as high (TTU: high = 58%, medium = 42%, and low = 0%; UWyo: high = 57%, medium = 39%, low = 4%). Students were also asked if they had used CD-ROM-based instruction in other classes. Only about half the students had been exposed to this form of instruction (TTU = 54%; Uwyo = 44%). Generally, these percentages were encouraging, but cumulatively, they indicated several potential sources of difficulty that students could face in accessing and using the CD-ROM resources that we were implementing in these classes. Some of these problems could be addressed by directing students to university facilities, but others had to be addressed directly by the instructors when revising and delivering the course materials.

At the University of Wyoming, the questionnaire data were supplemented by structured personal interviews at the end of the course [12]. Early on, up to 80% of the students indicated that they had technical problems with the CD-ROMs. Students also suggested that the frustrations generated by technical difficulties tended to make the CD-ROM less relevant to meeting the goals of the course. Our findings are consistent with others who have observed the impact of technology failures upon user satisfaction and perception of value [13]. The interview data were important early in development in focusing attention on the technical difficulties, albeit sometimes minor, that discouraged students from using the materials.

Time students allocated to learning resources

A second set of measures that we used in implementing the CD-ROM materials consisted

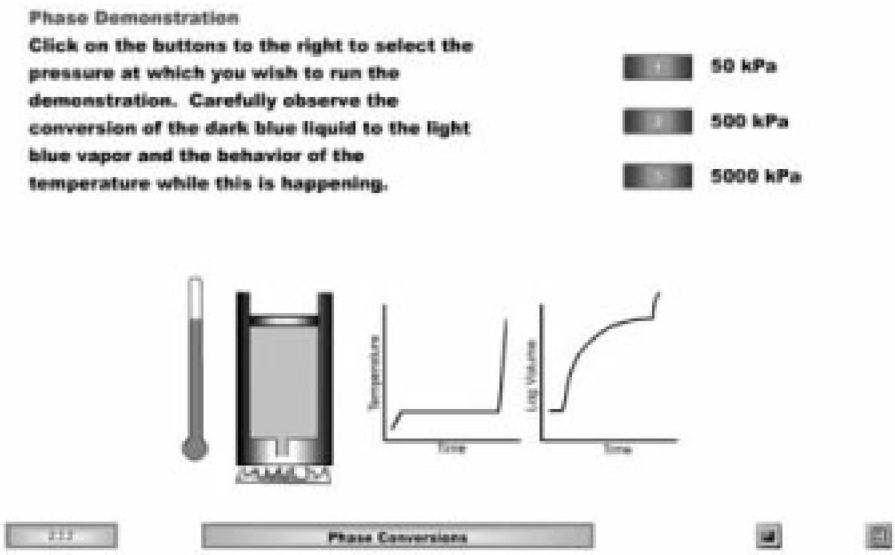

Fig. 5. Experimental simulation interaction example.

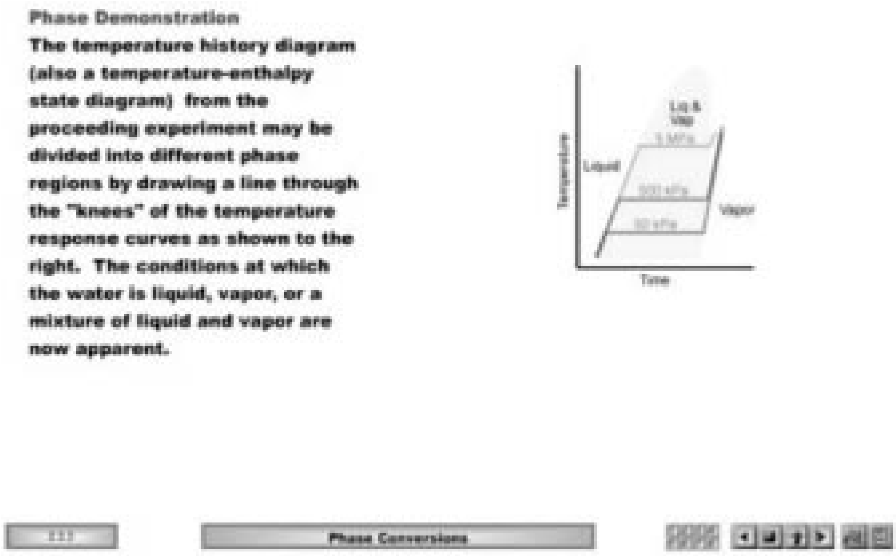

Fig. 6. Experimental simulation conclusion screen.

of estimates of the amount of time students spent on course materials [14]. The rationale for an interest in knowing about all of the students' study activities was the recognition that the CBI materials that we developed were part of a larger picture, and that some understanding of typical student study behaviors was necessary in order to understand how the CBI materials might fit into the curriculum as a whole. Through daily logs, which students used to keep a record of behaviors associated with the thermodynamics classes, we learned that the mean class attendance per week was 2.07 hours (standard deviation = 1.05), and mean study time was 6.91 hours ($SD = 3.96$), the latter exceeding the standard expectation of two hours of study outside of class for each credit hour. (Introduction to Thermodynamics is a three-credit course.)

The dominant activities were attending lectures and doing textbook homework problems, accounting for nearly half of the total time spent by students on this course. In a sample of 211 students, over a span of three semesters, the average time spent using the CD-ROM materials was 0.23 hours (SD = 0.63) i.e., less than 15 minutes per week! These data showed that students allocated a significant amount of time to this course, and that increasing the levels of students' engagement with CBI materials would require adjusting other demands that were being made of them, primarily assigned textbook problems.

Navigation patterns through the CD-ROM modules

About two-thirds of the CD-ROM screens consist of expository text. Nearly all screens begin with a narrative voice-over. The other one-third of the screens incorporate interactions that require the student to respond in meaningful ways. In two case studies [15], we examined the times that students spent on different components of the CD-ROM materials, and how they proceeded through the materials. This was accomplished through the use of *audit trails* [16], which are records of all the responses students make as they work through CBI materials. By summarizing and analyzing the audit trails, we were able to ascertain how students progressed through the CBI materials, click-by-click, page-by-page, and chapter-by-chapter.

The results that are described next are based on a sample of 31 students, which consists of 70% of the enrolled students in an intact course. The students spent about 30% of their total screen times listening to the narrations. The remaining 70% of the time was spent examining the text and figures and engaging the interactive elements. On average, students spent 31 seconds on screens without interactive elements, 46 seconds on pages with interactive elements, and 52 seconds on quiz pages. Overall, these data indicated that students were using these materials as the instructor intended. They continued to explore and process the materials on the pages long after the narration ended, and they devoted greater time to those pages that required active interaction on their part.

Figure 7 provides a summary of students' moves through the CD-ROM screens. These results are typical of those from other cohorts of students that we have tested. The figure shows that after finishing a page, students typically went to the next page (92.6%), using either the *next page* button (76.0%) or by going through the Table of Contents (TOC) (16.6%) for that section of the module. (Typically, students went to the TOC when they reached the last page of a section.) Other researchers have observed this linear usage pattern for other forms of CBI [16]. In ongoing research, we are striving to determine the ways in which moving forward one page is an adaptive form of navigation given the nature of the learning materials, students' background knowledge, students' perceptions of the learning task, and students' learning goals, and to what extent it reflects limitations in the software or metacognitive strategies of the user.

It is well known that successful college readers form specific reading goals, and look back and jump forward while reading in order to achieve those reading goals [17]. Because these are explicit and intentional behaviors about cognitive processing, they are labeled *meta*cognitive. Through the selection and application of metacognitive strategies, the reader monitors and guides comprehension. The navigation patterns in our data did not indicate very much metacognitive processing.

How students think about the concepts and the media

In order to gain insight into students' cognitive processes as they worked through the CD-ROM materials, we collected 'think aloud' protocols [18] as student volunteers worked through portions of the CD-ROM. In the think-aloud method, students are asked simply to report what they are thinking as they process the materials, without attempting to interpret or summarize the materials for the experimenter, unless those interpretations or summaries are a natural part of their thought processes. The data are collected one person at a time, and are tape-recorded for later transcription. During data collection, the primary role of the experimenter is to prompt the student regularly to continue to verbalize his or her thoughts. Following the think-aloud session, participants completed several open-ended and forced-choice questions.

The 20 participants in this study produced a total of 1327 verbalizations, at a rate of about 1.66 verbalizations per minute. Eighty-two percent of the comments that participants made were about comprehending the text. Only 14% of the comments expressed comprehension difficulty. The relatively low proportion of comments expressing confusion indicated that the materials were comprehensible. On the other hand, the comments that were made consisted largely of a reiteration of the content on the screen, either through reading the text out loud, or describing or summarizing the text, narration, a graph, or interactive element. These findings were consistent with those of the linear learner described earlier, and indicated a relatively low level of cognitive sophistication on the part of these readers in terms of the metacognitive strategies that they applied to understanding these science texts [18, 19]. Together, these findings suggest that additional improvement in the impact of the CD-ROM may depend on increasing the cognitive sophistication of the students using the materials.

In the open-ended questions, participants provided some very specific suggestions for improving the software, including the ability to turn the narration off, and including explanations for answers to questions. In the rating task, participants gave high ratings to several potential changes to the CD-ROM, including providing a search function for the entire CD-ROM, and including a subject index. Students responses to these questions were consistent with the high percentage of comprehension-related verbalizations described earlier, and indicated that students were engaged with the materials and that they were active processors, not passive processors.

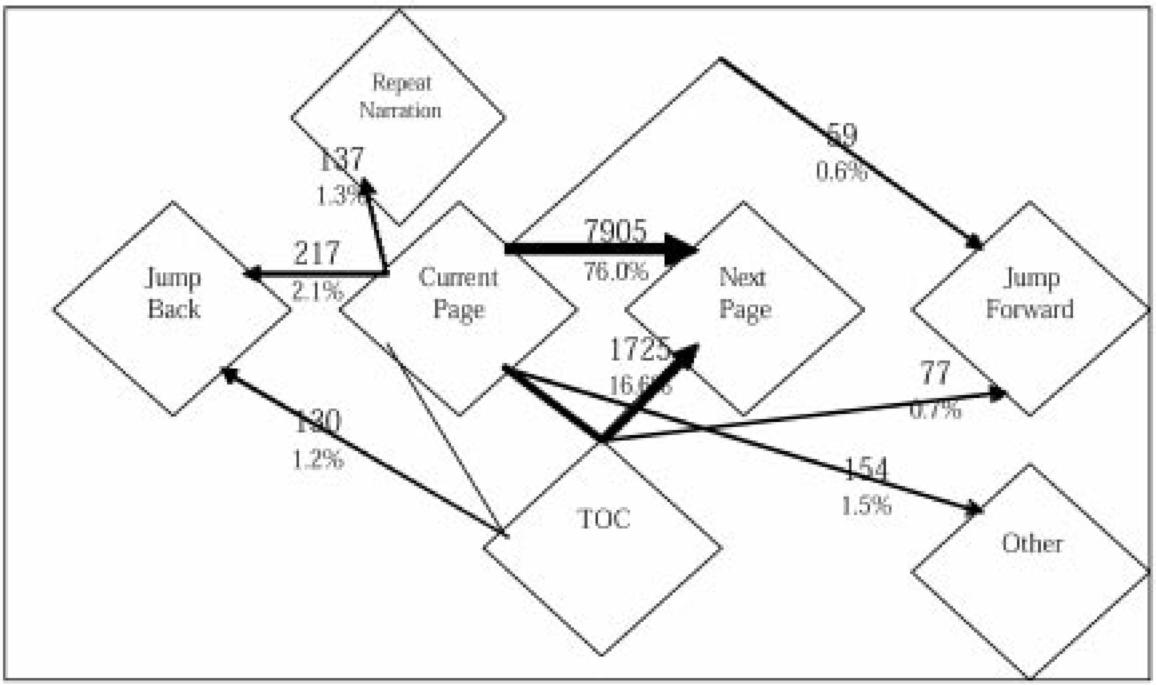

Fig. 7. Analysis of user navigational patterns.

The impact the CD-ROM on course mastery

Whether course materials, assignments, and other activities have an impact on student learning must become a central concern in assessment. Students have limited time for academics [20]. As educators, we must search for the means of making students' use of time efficient and productive.

In the research involving study logs [14] described earlier, the five most frequently reported learning activities were attending lecture, solving textbook problems, completing on-line homework problems, reading the textbook, and using the CD-ROM. In a sample of 61 students representing an intact class, the time that students reported using the CD-ROM was positively correlated with the time students spent using the other learning resources. CD-ROM times were also positively correlated with students' test average for the course. Due in part to the small sample size, only the correlation of CD-ROM times and on-line homework times was statistically significant. In the future, we hope to confirm the general pattern of mutual support in the use of learning resources (e.g., using the CD-ROM *and* the textbook), as well as the positive contribution of CD-ROM use to course performance, as measured objectively by indicators like test grades.

CONCLUSIONS

In this paper we illustrated the application of active learning techniques to CBI learning modules for a typical engineering Introduction to Thermodynamics course. These techniques are but a small set of many possibilities, and the final set of Introduction to Thermodynamics modules contains several others. Interested readers may view these at www7.tltlc.ttu.edu/thermotutorial in the URL. The set presented in this paper was selected specifically to demonstrate alternative ways of asking multiple-choice and short answer questions, because many teachers feel that these formats are too restrictive for science and engineering purposes. These interactive questions, as well as clickable figures and animations, and narrative voice-overs, are representative of the various tools that are available to contemporary curriculum developers to engage students in their own learning processes.

We also described the ongoing application of a set of complementary assessment methods that were applied to this project, consistent with our assumption that simply developing good computer-based instructional materials will not be sufficient in guaranteeing their usability and impact on student learning. The data suggested that most students were prepared to use computer-based instruction—i.e., they had access to computers and were skilled in the use of computers—but even minor technical problems were sufficiently frustrating to discourage students from using the CD-ROM materials. The use of audit trails indicated that, in general, students used the materials as intended by the instructor, dwelling longer on those pages that required student interactions. The audit trails furthered showed that these students were linear learners in the context of using these materials. Other research has indicated that *non-linear* text processing patterns typify expert college readers, thus the linear pattern raises some concern about the metacognitive processing applied to comprehending the CD-ROM materials. There was no evidence in an independent set of data to indicate that students were comprehending the material in a deep fashion, as would be indicated by more metacognitive comments—e.g., raising questions, making predictions, constructing inferences, and evaluating the content. In spite of these limitations, correlations between time spent using the CD-ROM, the use of other learning resources, and test performance, have been positive, in the data reported here and elsewhere [15], indicating that the CD-ROM was a useful learning resource for introductory thermodynamics students.

Acknowledgements—This project was sponsored by the U.S. National Science Foundation under CCLI grant 0089410.

REFERENCES

1. S. Reisman, and W. A. Carr, Perspectives on multimedia systems in education, *IBM Systems Journal*, **30**(3) 1991, pp. 280–295.
2. A. A. Renshaw, J. H. Reibel, C. A. Zukowski, K. Penn, R. O. McClintock and M. B. Friedman, An assessment of on-line engineering design problem presentation strategies, *IEEE Trans. Education*, **43**(2) 2000, pp. 83–89.
3. I. Aedo, P. Diaz, C. Fernendez, G. Munoz Martin and A. Berlanga, Assessing the utility of an interactive electronic book for learning the PASCAL programming language, *IEEE Trans. Education*, **43**(3) 2000, pp. 403–413.
4. J. A. B. Grimoni, L. Belico dos Reis and R. Tori, The use of multimedia in engineering education—an experience, *ICEE Proc.*(1998). www.ineer.org
5. S. M. Holzer and R. H. Andruet, Experiential learning in mechanics with multimedia, *Int. J. Eng. Ed.*, **16**(5) 2000, pp. 372–384.
6. A. R. Huson and K. M. Kavi, Interactive teaching practices in small class sizes while cutting into the high cost of education, *ICEE Proc.* (1999). www.ineer.org
7. C. Salzmann, D. Gillet and P. Huguenin, Introduction to real-time control using LabView™ with an application to distance learning, *Int. J. Eng Ed.*, **16**(5) 2000, pp. 372–384.
8. Y. A. Cengel and M. A. Boles, *Thermodynamics: An Engineering Approach*, Edn 4, McGraw-Hill (2001).

9. B. S. Bloom, *Taxonomy of Educational Objectives: The Classification of Educational Goals*, Committee of College and University Examiners, New York, David McKay Co., Inc., (1956).
10. A. W. Chickering and Z. F. Gamson, Seven principles of good practice, *AAHE Bulletin*, **39**(3–7) 1987.
11. R. Taraban, E. E. Anderson, M. P. Sharma and M. W. Hayes, Monitoring students, study behaviors in thermodynamics, *Proc. 2002 ASEE Anuual Conf.*
12. M. P. Sharma, E. E. Anderson and R. Taraban, A study of students' perceptions of computer-based instruction in introductory thermodynamics courses, *ASEE Annual Conf. and Exp.*, Nashville, TN, 2003.
13. M. Sanders and E. McCormich, *Human Factors in Engineering and Design*, 7th Edn, McGraw-Hill, NY (1993).
14. R. Taraban, M. W. Hayes, E. E. Anderson and M. P. Sharma, Giving students time for the academic resources that work, *Journal of Engineering Education*, pp. 205–210, 2004.
15. R. Taraban, E. E. Anderson, M. P. Sharma and A. Weigold, Developing a model of students' navigations in computer modules for introductory thermodynamics, *ASEE Annual Conf.*, Nashville, TN (2003).
16. E. R. Misanchuk and R. A. Schwier, Representing interactive multimedia and hypermedia audit trails, *J. Educational Multimedia and Analysis Methods*, **1**, 1992, pp. 355–272.
17. R. Taraban, K. Rynearson and M. Kerr, College students' academic performance and self-reports of comprehension strategy use, *J. Reading Psychology*, **21**, 2000, pp. 283–308.
18. M. Pressley and P. Afflerbach, *Verbal Protocols of Reading: The Nature of Constructively Responsive Reading*, Erlbaum, Hillsdale, NJ (1995).
19. J. Otero, J. León and A. Graesser (Eds.), *The Psychology of Science Text Comprehension*, Erlbaum, Mahwah, NJ (2002).
20. T. J. Zielinski, D. W. Brooks, K. J. Crippen and J. L. March, Time and teaching, *J Chemical Education*, **78**, 2001, pp. 714–715.

Edward E. Anderson is Professor of Mechanical Engineering at Texas Tech University where he is also the Director of the University Teaching, Learning, and Technology Center. His responsibilities at the Center are to train and assist faculty throughout the university in applying technology to their teaching. He received his Ph.D. degree from Purdue University. Recently, he has produced seven CBI textbook supplements covering topics ranging from electrical circuits to thermodynamics as well as the Fundamentals of Engineering examination.

Roman Taraban is Associate Professor in the Department of Psychology at Texas Tech University. He received his Ph.D. in cognitive psychology from Carnegie Mellon University. His interests are in how undergraduate students learn, and especially, how they draw meaningful connections in traditional college content materials (e.g., textbooks, lectures, multi-media).

M. P. Sharma is Professor of Chemical and Petroleum Engineering at the University of Wyoming. He received his Ph.D. degree in Mechanical Engineering from Washington State University. A current area of interest is conducting research on teaching and learning methods. He has developed an online course for Engineering Thermodynamics that is fully deliverable by Internet to remote and on-campus students. He has been teaching this course as he continues to conduct research and development of it.