Developing a Model of Students' Navigations in Computer Modules for Introductory Thermodynamics

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Abstract

Active learning techniques were incorporated into modules on a CD-ROM and were provided to students in introductory thermodynamics at Texas Tech University and the University of Wyoming during two semesters. The active learning techniques included interactive exercises, graphical modeling, physical world simulations, and exploration. We were interested in how students used these materials, and how we might improve them. In two case studies, students' interactions with the CD were automatically recorded to a computer file and provided detailed logs of students' page navigations and their behaviors and performance with interactive elements. From these logs, we described their behaviors and inferred their reading and metacognitive goals and strategies. The analyses were used to propose changes to the implementation and delivery of the materials.

Introduction

A goal of new initiatives in engineering education is to use computer and multi-media technology to help students become successful, active learners. Theoretical models of learning[1] proposed that active learning was not the result of a single factor but of several related factors working together, as follows. Active learners consider the nature of the

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materials, the tasks, assignments, and knowledge for which they are accountable. They are cognizant of their own strengths and weaknesses and plan their work accordingly. They know and select appropriate processing and learning strategies as a function of the materials, task requirements, and personal characteristics. Other research has shown that it is difficult to understand and predict students' academic behaviors because they are influenced by a large number of course features. Most certainly, teachers exert control over student learning behaviors through the number and nature of assignments in a course—i.e., through the demands they made of students. Teachers also strongly influence what students do through course compensations, for example, by providing ways of making up missed work, or gaining extra credit. Course compensations reduce student effort[2]. In general, educational researchers do not have best strategies or methods of studying to recommend for students[3]. Student behaviors—their successes and failures—are best understood in the context of specific courses, in terms of course requirements and demands, the nature of the materials, and the characteristics of the students, including factors like motivation, expectations, and background knowledge. This brief review is meant to highlight the complexity of doing field-based research. We cannot assume that if we simply develop good materials and make them available to students, that the materials will automatically have a positive impact on learning.

The present paper describes our research on introductory thermodynamics students' use of a supplemental CD that was used to deliver course content and related "hands-on" interactions. This is part of a multi-year study in which this CD and related computer-based materials are being implemented into the thermodynamics course. In other papers[4,5], we described the course materials and students in some detail, which may be useful to the reader in situating the present research. After describing the CD materials, we focus on five general questions, with the last one being the most important:

- How much time did students spend on the CD?
- How did students distribute their time?
- Were there any distinct patterns of navigation through the CD?
- Did CD use correlate with quiz and test scores?
- How can we use data like these to learn about and to improve the effectiveness of supplemental course materials like these?

Often, research on computer navigation has been conducted in controlled lab settings[6,7,8], in which participants were given explicit tasks to carry out. This method excludes important factors that are part of situated learning—i.e., learning in real classrooms—where students define their own conditions of learning, set personal goals, and apply learning strategies on an individual basis. A contribution of the research here is that it communicates a sense of how students use software implemented in a real course. In the discussion, we ask how the present findings can be used to improve the effectiveness of the CD.

An Interactive CD for Introductory Thermodynamics

E. E. Anderson (see authors) authored the CD used in this study. It was designed to go along with the book *Thermodynamics: An Engineering Approach*, 4th ed., by Cengel and Boles[9], and is provided by the publisher with the textbook. In order to assure content

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validity, the CD materials were coordinated with the textbook. The first six chapters of the textbook and CD are relevant to the case studies reported here. The CD titles, which are comparable to the text titles, are *Introduction to Thermodynamics*, *Thermodynamic Properties*, *Energy Transfer*, *First Law of Thermodynamics*, *Second Law of Thermodynamics*, and *Entropy*.

Organization of the CD—When students open the CD, they are presented with the main table of contents showing the six chapter titles. Upon choosing a chapter, they go to the chapter table of contents. As an example, chapter 1 contains the subchapters *Introduction*, *Dimensions and Units*, *Systems*, *Basic Properties*, *States and Equilibrium*, *Processes*, *Energy*, *Environmental Impact*, *Temperature*, *Pressure*, *Hydrostatic Pressure*, *Atmospheric Pressure*, and *Solving Problems*. After choosing a subchapter, the students go to the first page in the chapter. The pages contain combinations of text, interactive and non-interactive graphics, interactive and non-interactive animations, and multiple choice and short-response quizzes. Figure 1 provides an example of an interactive graphic, and Figure 2 displays a quiz page. When students first open a page, they hear a narration related to the subject matter on the page. The text and figures on the page add additional information. After the narration, several controls appear. These are for jumping forward to another page in the subchapter, moving one page forward or back, going to the table of contents, and printing the page (see Figure 2, bottom right). The distribution of pages with non-interactive and interactive elements, and quizzes, broken down by chapter can be seen in Table 1. An abbreviated description of the CD pages is in the Appendix. Table 1 shows the proportion of interactive and quiz pages to total pages (*mean* = .34). From the relatively high proportion of pages requiring student interaction, it should be evident that the CD provides many opportunities for active learning. An examination of Figures 1 and 2 shows the detail and care with which individual pages were created. Therefore, this first version of the CD appeared to fulfill the goal of developing attractive formats with many opportunities for students to interact with the course content.

Table 1: Number of Screens by Type of Content and Chapter

	Non-Interactive	Interactive (I)	Quizzes (Q)	Total (T)	(I + Q) / T
Chapter 1	41	7	14	62	.34
Chapter 2	27	8	19	54	.52
Chapter 3	22	1	9	32	.31
Chapter 4	47	1	11	59	.20
Chapter 5	27	3	10	40	.33
Chapter 6	43	4	19	66	.35
Total	207	24	82	313	.34

Note. (I + Q) / T represents the proportion of interactive and quiz pages to total pages.

Case Study I

Participants—The participants were 23 students at the University of Wyoming who were enrolled in *Thermodynamics* (ES2310) during summer 2002. Fifteen students—i.e., 65% of the enrolled students—submitted floppy disks with a record of their interactions.

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Figure 1: Example Of An Interactive Page

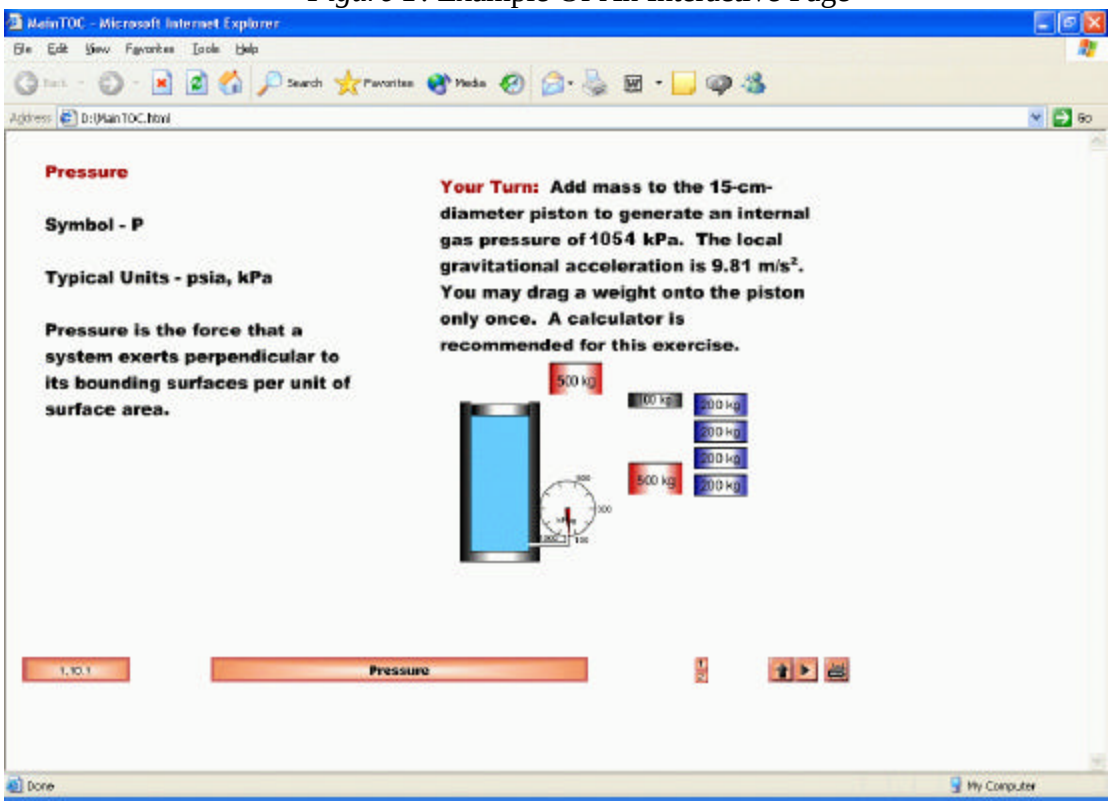
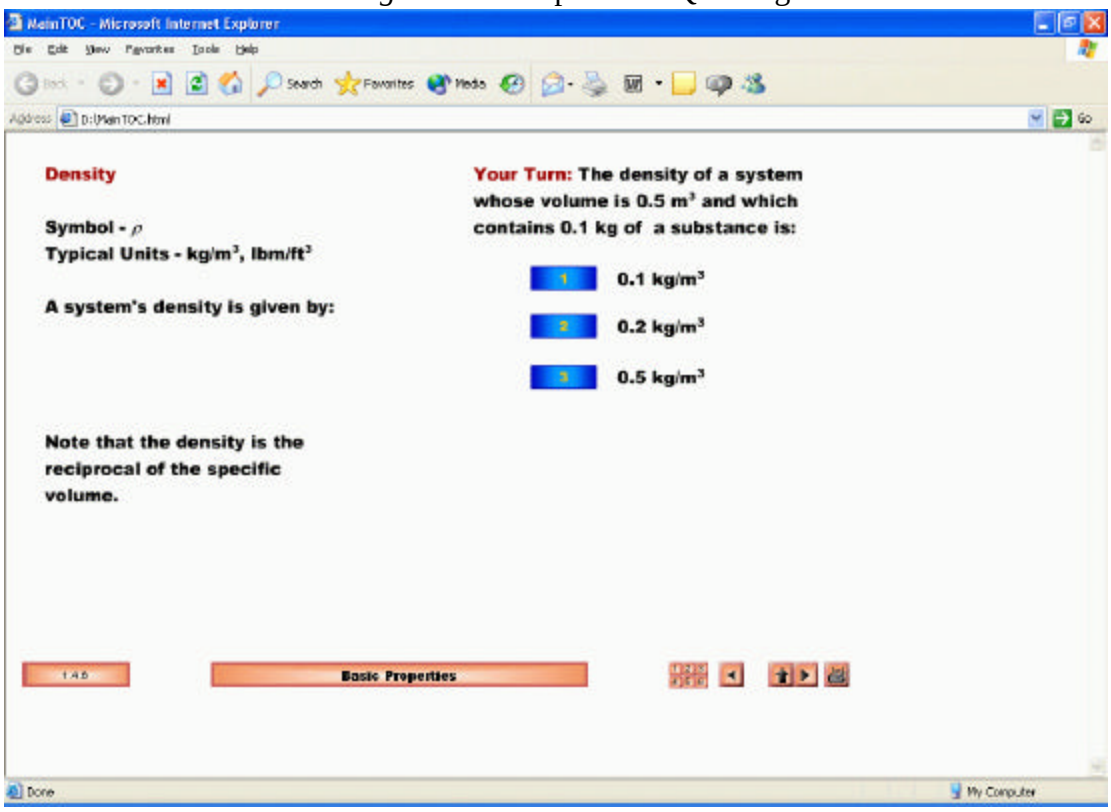


Figure 2: Example Of A Quiz Page



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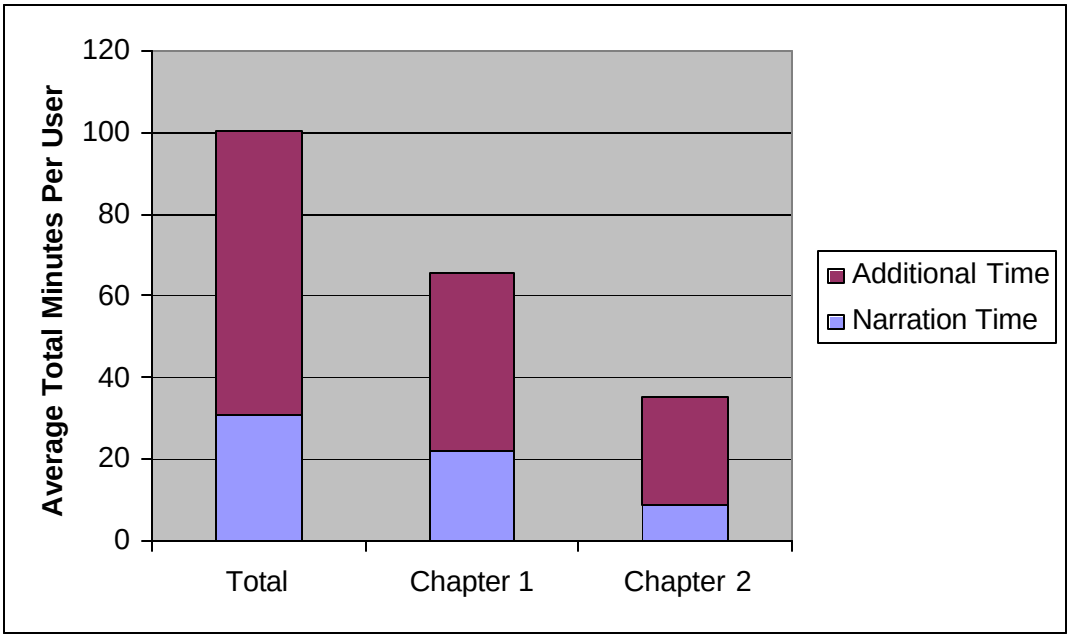
Materials—A specially formatted CD was developed that collected student interactions on a floppy disk that was subsequently submitted to the instructor. The CD coincided with the first two chapters of the course textbook. The CD and floppies were provided to all students at no cost.

Procedure—The instructor described the CD materials to students and encouraged them to use the CD in order to improve their grades on class homeworks and tests. Use of the CD was voluntary, however, students received extra credit if they turned in the floppy disk that recorded their interactions. Extra credit was equal to the points associated with two (out of twelve required) written homework assignments.

Results—Participants spent a mean total of 101 minutes in the two chapters, as shown in Figure 3. Although the chapters were similar in length and interactions (see Table 1), there was a 47% drop in average times from Chapter 1 to Chapter 2, suggesting that students lost interest in the CD quickly. This possibility was examined further in Case Study II. Each page contained narration that added to the content—it was not identical to the text. A breakdown of total time into the time spent listening to the narration (*mean* = 31 minutes) and additional time looking at the page (*mean* = 70 minutes) showed that students were processing the text, figures, and interactions on the pages. They were not simply waiting for the narration to end in order to navigate to the next page.

Figure 3: Case Study I -- Average Participant Total Time (in minutes) by Chapter and by Activity



The Distribution of Times by Content—Figure 4 shows the total time spent on the three kinds of screens (see Table 1), and Figure 5 shows times per page. On average, students spent 35 seconds on pages without interactive elements, 54 seconds on pages with interactive elements, and 76 seconds on pages with quizzes. The time-per-page data in

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Figure 5 are important because they showed that participants spent more time on pages that demanded more interaction—i.e., interactive and quiz pages compared to non-interactive (those with narration, text, figures) pages. This provided some evidence that participants were using the materials as intended by the instructor.

Figure 4: Case Study I -- Average Participant Total Time (in minutes) by Type of Content

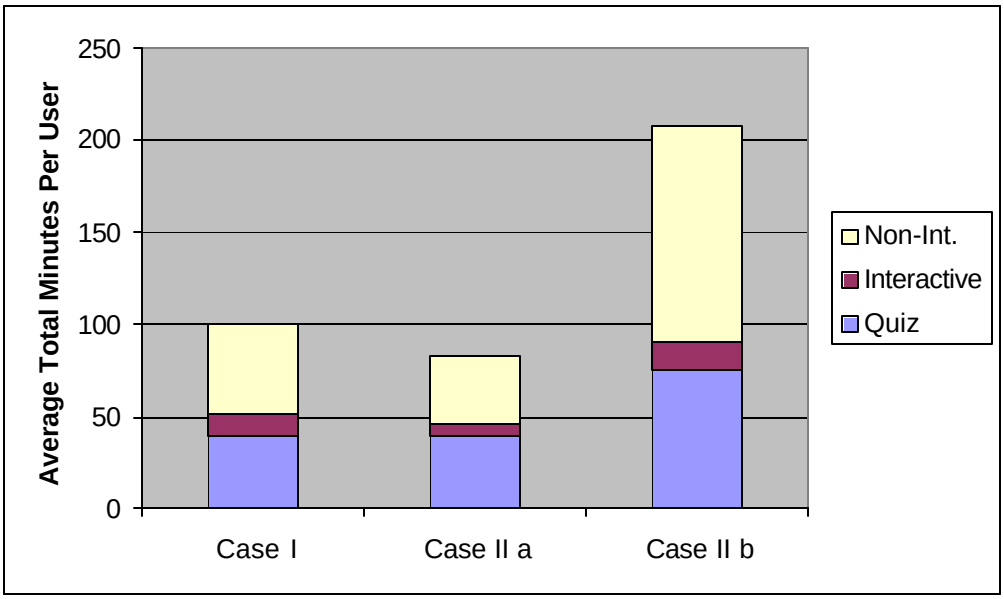
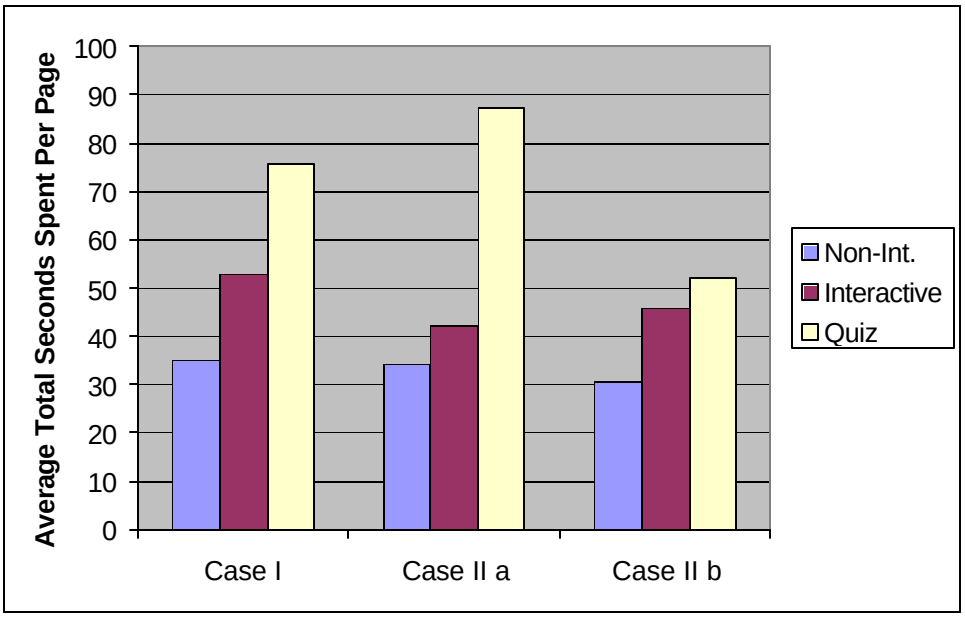


Figure 5: Case Study I -- Average Participant Time (in seconds) Per Screen by Type of Content



The Distribution of Times by Participant—Figure 6 summarizes the behavior of individual students. Total times varied from a high of 288.40 minutes to a low of 14.60

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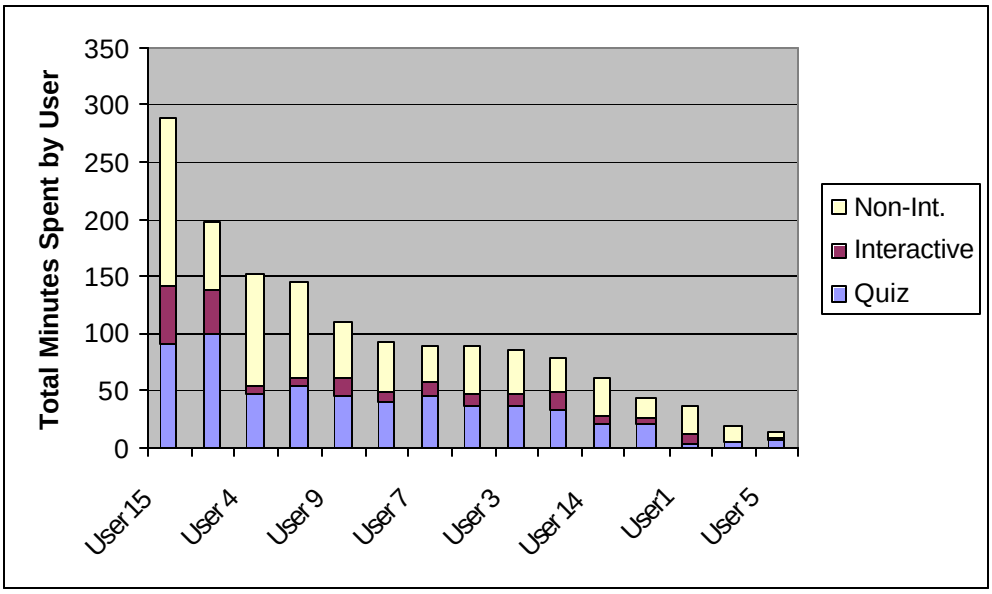
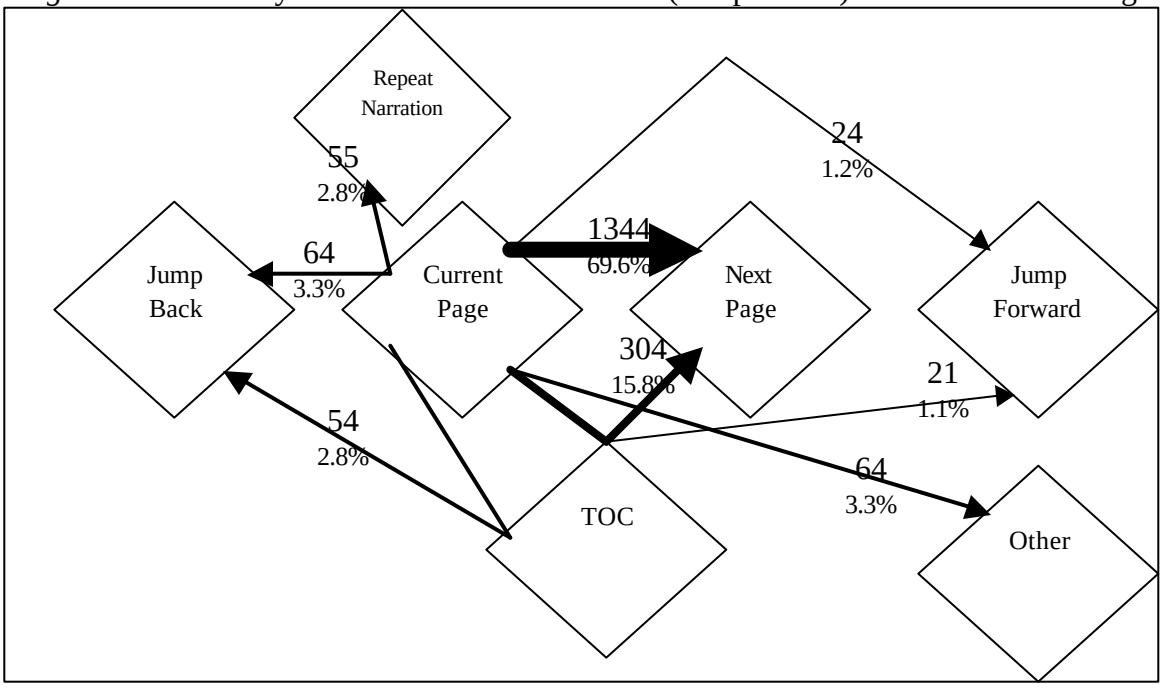
minutes, with a mean of 100.28 minutes, and a standard deviation of 72.36 minutes. The times were generally normally distributed.

Figure 6: Case Study I -- Average Participant Total Time by Type of Content



Patterns of Navigation—In order to carry out this analysis, we counted up the kinds of moves participants made from their current page. The navigational patterns are depicted in Figure 7. After finishing a page, participants went to the following page 85.4% of the time, using either the next page button (69.6%) or the table of contents (15.8%). It should be noted, that it was not always possible to access the next page using the next page

Figure 7: Case Study I -- Total Number of Moves (and percents) From the Current Page



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button, as at the end of each sub-chapter, the user had to access the following sub-chapter via the table of contents.

All other destinations accounted for only a small portion of the total moves. Students went back to a previous page in 6.1% of all cases, and jumped forward in 2.3% of all cases. All other options, such as replaying the narration, printing the page, or quitting the program accounted for another 6.1%.

Relation of Time to Performance Tests—Correlations were calculated between several measures of CD time and participants' average score on CD quizzes as well as the in-class test score that coincided with the CD. The results are summarized in Table 2. Because *time-on-task* measures are generally positively correlated with performance measures[10], we expected longer times on non-quiz (content) pages to be associated with higher quiz and test scores. The correlations with test scores were in the direction of the prediction, however, the correlations with CD quiz scores were not. There was no clear prediction for quiz pages. The trends in the correlations showed students who spent more time on quiz pages did more poorly on the CD quizzes, but they did better on the in-class test. The overall pattern of correlations suggested that students used the CD to learn the course content for purposes of doing well on the in-class tests. Because the CD quizzes did not affect their course grades, there was no incentive for students to do well on the CD quizzes. The small *N* of 15 in this study reduced the likelihood of reaching statistical significance in the correlations.

Table 2: Pearson Correlations Between Time and Quiz and Test Scores

	Total Time on Non-Quiz Pages	Average Time per Page on Non-Quiz Pages	Total Time on Quiz Pages	Average Time per Page on Quiz Pages
Mean Quiz Scores	-.514*	-.418	-.307	-.275
Test Score	.340	.359	.441	.491

Notes. $N = 15$. * $p < 0.05$ (2-tailed)

Case Study II A and II B

Participants—The participants in Case IIA were 36 students at the Texas Tech University who were enrolled in the course *Engineering Thermodynamics* I (ME2322). Participation was voluntary and students did not receive extra credit for returning floppy disks with interactions to the instructor. Eight students—22% of the enrolled students—submitted floppies with readable data. The participants in Case Study II B consisted of 44 students at the University of Wyoming who were enrolled in the course *Thermodynamics* (ES2310). They were drawn from the same population as Case Study I and received extra credit as described in Case Study I. Thirty-one students—70% of the enrolled students—returned floppies with readable data to the instructor.

Materials—The CD was formatted to collect interactions from Chapters 1 to 6 (see Table 1) and was provided to students at no cost along with a floppy disk.

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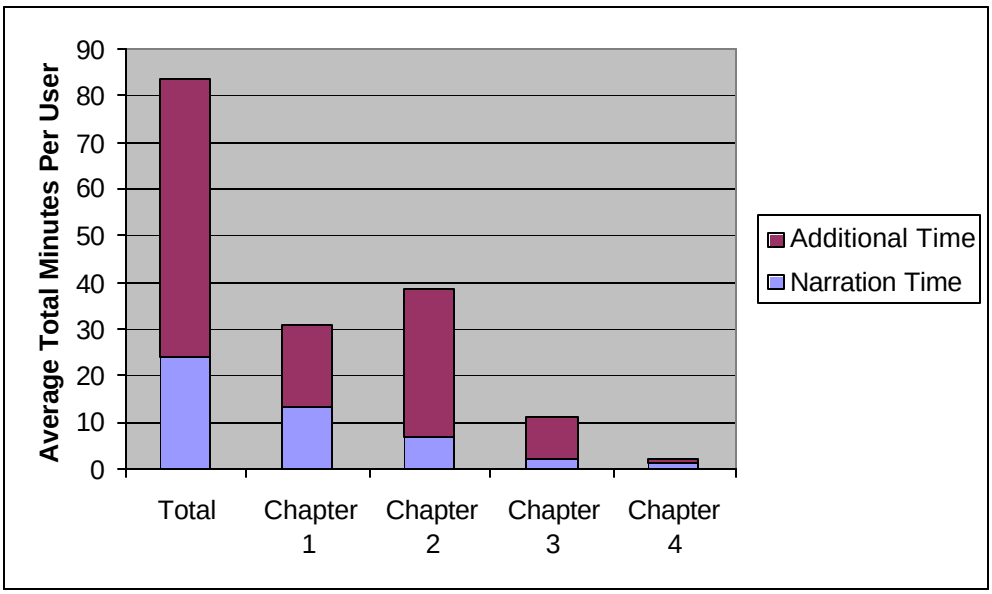
Procedure—Case Study II was conducted during fall 2002. The procedure was identical to that followed in Case Study I except that instructors differed in how they assigned extra credit (see Participants).

Results for Case Study II A—In Case II A, participants spent a total of 83 minutes, on average, using the CD, with 24 minutes (28.9%) devoted to listening to the narration and 59 minutes (71.1%) of additional time looking at the page and using the interactive elements. See Figure 8. Broken down by chapter, they spent 31 minutes (36.9%) on Chapter 1, 39 minutes (46.4%) on Chapter 2, 12 minutes (14.3%) on Chapter 3, 2 minutes (2.4%) on Chapter 4, and did not open Chapters 5 or 6. This pattern was consistent with the findings in Case Study I where participants appeared to lose interest as they worked through the CD materials.

Figure 8: Case Study II A -- Average Participant Total Time (in minutes) by Chapter and Activity



The Distribution of Times by Content and by Participant—Total times by type of content are summarized in Figure 4. As shown in Figure 5, the distribution of time between the three types of elements was on average 34.21 seconds per page for pages without interactive elements, 42.19 seconds per page for pages with interactive elements, and 87.35 seconds per page for pages with quizzes. These data are consistent with the conclusion that students used the pages as the instructor intended, with greater time devoted to those pages that required active interaction on the part of the user. Figure 9 summarizes times for individual students. Average total times varied from 214.30 minutes to 6.18 minutes, with a mean of 83.33 minutes, and a standard deviation of 65.83 minutes.

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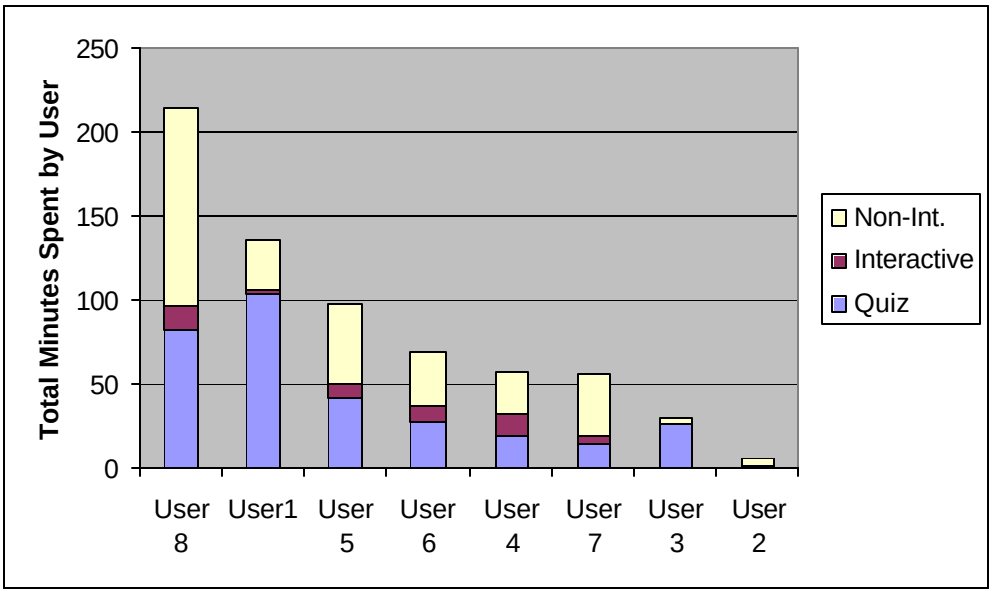
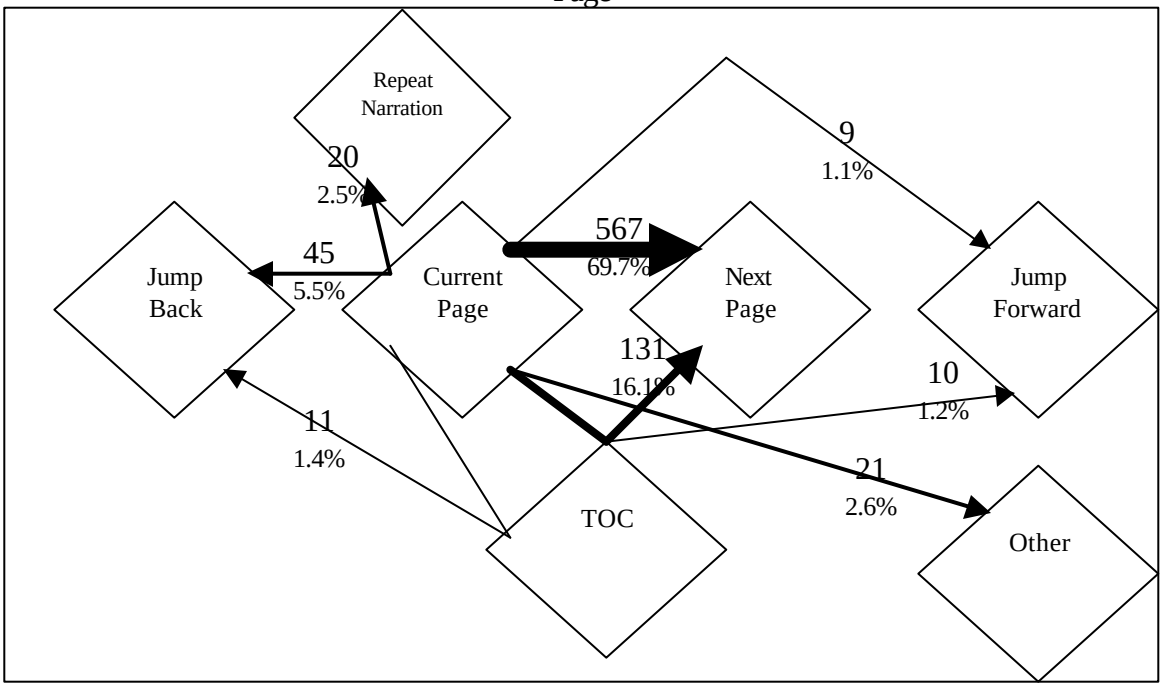
Figure 9: Case Study II A -- Average Participant Total Time (in minutes) by Type of Content



Patterns of Navigation—A summary of participants' moves through the CD screens is shown in Figure 10. After finishing a page, users typically went to the following page (85.5%), using either the next page button (69.7%) or the table of contents (16.1%). This replicated the pattern from Case Study I in which there were few moves back to review screens and few jumps forward to preview screens.

Figure 10: Case Study II A -- Total Number of Moves (and percents) From the Current Page



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Results for Case Study II B—Similar analyses were conducted for Case Study II B. In contrast to the participants in Case Study I and II A, these students showed a more uniform distribution of time across the six chapters of material, as summarized in Figure 10. Total times for the three types of elements are shown in Figure 4. The distribution of time between the three types of elements was on average 30.52 seconds per page for pages without interactive elements, 45.84 seconds per page for pages with interactive elements, and 52.03 seconds per page for pages with quizzes, as summarized in Figure 5. Figure 11 shows that individual students spent total times ranging from 456.20 minutes to 56.23 minutes, with a mean of 206.86 minutes, and a standard deviation of 100.28 minutes.

Figure 10: Case Study II B -- Average Total Time (in minutes) by Chapter and Activity

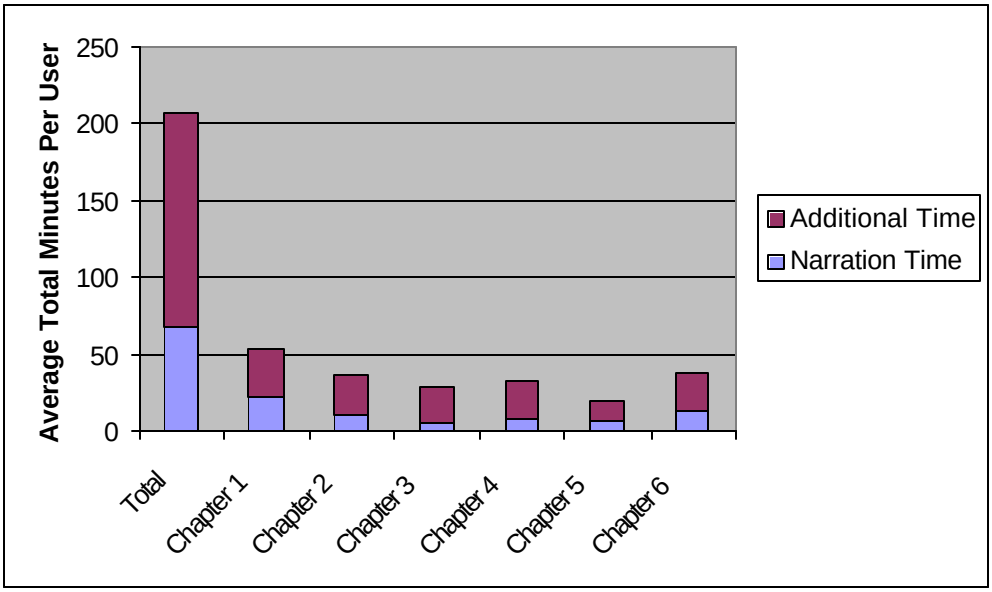
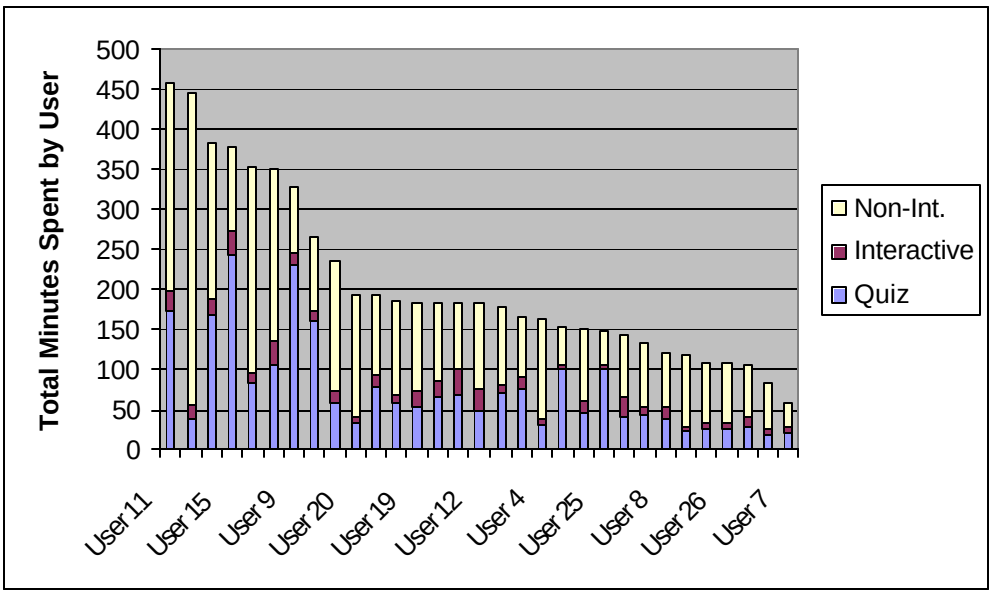


Figure 11: Case Study II B -- Average Participant Total Time by Type of Content



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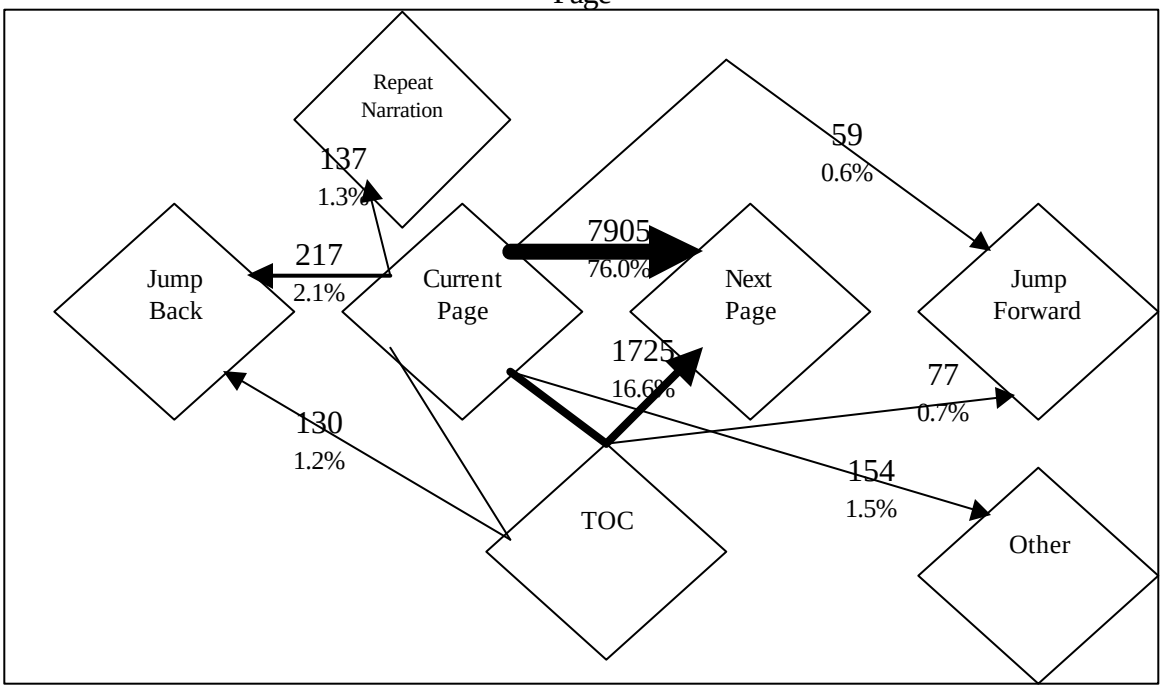
A facet of Figure 11 that is particularly striking is the differences across participants in time allocation to the three types of content. This appears true even in cases where total time is relatively similar. This suggests that participants differed in background knowledge, and they applied different goals and strategies as they used the CD.

Participants' moves through the screens are depicted in Figure 13. These results replicated the patterns already described, in which users largely click forward to the next screen when working through the materials.

Figure 13: Case Study II B -- Total Number of Moves (and percents) From the Current Page



Correlations were calculated between participants' average CD quiz scores, the mean of two in-class test scores that coincided with CD content, and several measures of the time spent using the CD. The results are shown in Table 3. The positive correlations between time on non-quiz pages and quiz and test scores did not reach significance, but several were in the predicted direction. There was no evidence that spending more time on quiz pages helped on the in-class test, but more time was significantly related to higher quiz scores.

Table 3: Pearson Correlations between Time and Quiz Score and Test Scores

	Total Time on Non-Quiz Pages	Average Time per Page on Non-Quiz Pages	Total Time on Quiz Pages	Average Time per Page on Quiz Pages
Quiz Score	.033	.144	.474**	.448*
Test Score	.334	.186	-.170	-.241

Notes. $N = 31$. * $p < 0.05$, $p < 0.01$ (2-tailed)

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Conclusions

In two case studies we attempted to learn about the effectiveness of CD materials that were developed to supplement Cengel and Boles' *Thermodynamics: An Engineering Approach*[9]. We accepted the suggestion from a partial review of research on college studying (see the Introduction) which indicated that few general assumptions could be made in advance about student study behaviors, and we implemented a method of unobtrusively observing students as they used the software. We propose the following tentative conclusions.

- **The CD materials have content validity.** The CD materials were authored to coincide with the *Thermodynamics* textbook, which assured that the CD materials were relevant to the course content.
- **The CD materials implement active learning.** The relatively high proportion of pages requiring interaction to non-interactive pages (see Table 1) allows for considerable student interaction with the learning materials.
- **The CD elements were used as intended.** Participants spent considerable time on non-interactive screens after the narration ended (see Figure 3). Participants also spent more time on pages with interactions than on pages without interactions (see Figure 5). This suggests that non-interactive and interactive materials engaged students as they were intended to do.
- **Participants worked through the CD in a linear fashion**. The typical pattern of navigation in the CD was to click to the next page. The pattern of movement appeared consistently in the three sets of data summarized here.
- **The CD did not bring about broad active learning.** Participants showed mixed patterns of interest in the CD materials. Total times by chapter in Case Study I and Case Study II A, but not in Case Study II B indicated that students were interested in exploring the CD, but their interest waned as they worked through the materials.
- **Students need strong course related incentives**. Of the 93 students in the thermodynamics courses, only 54 (58%) used the CD materials, based on the number of floppies with interactions that were returned to the instructors. Students exhibited this low level of interest even though one of the instructors did provide extra credit (Case Study I and Case Study II B), and even though both professors encouraged students to use the CD in order to improve their homework, quiz, and test grades.

The results of these case studies raise several important challenges for future research.

- Linear patterns of navigation through hypertext have been described in other research studies.[11] It is not clear whether moving one page forward has adaptive value for the student in materials like these. It will be important to determine the ways in which this may be an ideal form of navigation given the nature of the learning task and goals of the user, and to what extent is reflects limitations in the software and metacognitive strategies of the user. It is well known that expert readers form specific reading goals and look back and jump forward while reading in order to achieve those goals[12]. That type of navigation was not evident in the present data.

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- Individual patterns of engagement with the types of content pages varied widely suggesting that participants differed in background knowledge, and in the goals and strategies they applied to these materials. At present we have no information about users' metacognitive goals and strategies. In order to effectively design learning materials we will need to learn more about individual differences in the students who use the materials.
- It will be important to establish the predictive validity of these materials—i..e., to show that use of these materials results in better performance using objective measures, like in-class test performance. Several of the correlations reported here between CD use and test performance were in the predicted direction.

Other challenges include the following.

- It was not clear from the present findings whether students found the narration to be helpful. Multi-media research has suggested that learning can be hindered by a combination of narration and text.[7] Thus it would be helpful to gather more information from users about their perceptions of the utility of the narrations and to supplement these with performance measures.
- There is a need to explore incentives that motivate students to use supplemental materials like those provided by the CD. Clearly, a larger proportion of students were not sufficiently motivated to use these CD materials.
- There may be a need to re-design the materials to better maintain student interest throughout the chapters.
- Finally, does the CD "experience" enhance learning in unique ways – ways that could not be achieved using more traditional materials, like a textbook?

References

[1] Jenkins, J. J. In L. S. Cermak & F. I. M. Craik (eds.), *Levels of Processing and Human Memory (pp. 425-445);* Erlbaum: Hillsdale, NJ, 1978.

[2] Thomas, J., Bol, L., Warkentin, R., Wilson, M., Strage, A., & Rohwer Jr., W. *Applied Cognitive Psychology*,**1993,** *7*, 499-532.

[3] Nist, S. L., & Simpson, M. L. In M. L. Kamil, P. B. Mosenthal, P. D. Pearson, & R. Barr (eds.), *Handbook of Reading Research*, pp. 645-666; Erlbaum: Mahwah, NJ, 2000.

[4] Taraban, R., Anderson, E. E., Sharma, M. P., & Hayes, M. Presentation at the *2002 American Society for Engineering Education Annual Conference & Exposition.*

[5] Taraban, R., Hayes, M. W., Sharma, M. P., & Anderson, E. E. *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition.*

[6] Graesser, A. C., Langston, M. C., & Baggett, W. B. In G. V. Nakamura, R. Taraban, & D. L., Medin (eds.), *Categorization by Humans and Machines*, pp. 411-436; Academic Press: San Diego, CA, 1993.

[7] Mayer, R. E. Multi-Media Learning. Cambridge University Press: New York, NY, 2001.

[8] Schoemaker, M. J. N., & Mulder, L. J. M. In B. P. L. M. Den Brinker, P. J. Beek, A. N. Brand, F. J. Maarse, & L. J. M. Mulder (eds.), *Cognitive Ergonomics, Clinical Assessment and Computer-Assisted Learning*, pp. 15-21; Swets & Zeitlinger: Lisse, The Netherlands, 1999.

[9] Cengel, Y. A., & Boles, M. A. *Thermodynamics : An Engineering Approach,* 4th ed.; McGraw-Hill: Boston, MA, 2001.

[10] Taraban, R., Rynearson, K., & Stalcup, K. A. *Behavior Research Methods, Instruments, & Computers*, **2001**, 217-225.

[11] Misanchuk, E. R., & Schwier, R. A. *Journal of Educational Multimedia and Hypermedia*, **1992**, 355-372.

[12] Taraban, R., Rynearson, K., & Kerr, M. *Journal of Reading Psychology*, **2000**, 283-308.

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Appendix: Contents of CD-Rom

Note: The phrases provide brief descriptions of page contents. A dash (-) indicates a standard page with text and narration.

Page	Interactive Content
1.1.1.	Clickable Picture
1.1.2.	Clickable Picture
1.1.3.	Clickable Picture
1.1.4.	-
1.2.1.	-
1.2.2.	-
1.2.3.	1 * 3 choice quiz
1.2.4.	-
1.2.5.	-
1.2.6.	-
1.2.7.	1 * 3 choice quiz
1.2.8.	-
1.2.9.	-
1.2.10.	1 * 3 choice quiz
1.2.11.	-
1.2.13.	1 * 3 choice quiz
1.2.14.	1 * 3 choice quiz
1.2.15.	1 * 3 choice quiz
1.2.16.	1 * 3 choice quiz
1.3.1.	-
1.3.2.	-
1.4.1.	-
1.4.2.	-
1.4.3.	-
1.4.4.	1 * 3 choice drag quiz
1.4.5.	1 * 3 choice quiz
1.4.6.	1 * 3 choice quiz
1.5.1.	-
1.5.2.	-
1.5.3.	-
1.6.1.	-
1.7.1.	-
1.7.2.	-
1.7.3.	1 * 5 choice quiz
1.8.1.	-
1.8.2.	-
1.8.3.	-
1.8.4.	-
1.8.5.	-
1.8.6.	-
1.9.1.	-
1.9.2.	-
1.9.3.	3 * 3 option drag quiz
1.9.4.	3 * 3 option drag quiz
1.10.1.	1 * 3 option drag quiz
1.10.2.	Enter number, see change
1.11.1.	-
1.11.2.	Scuba Diver Up/Down
1.11.3.	Scuba Diver Sideways
1.11.4.	-
1.11.5.	Click +/–, see change
1.12.1.	-
1.12.2.	-
1.13.1.	-
1.13.2.	-
1.13.3.	-
1.13.4.	-
1.13.5.	-
1.13.6.	-
1.13.7.	-
1.13.8.	-
1.13.9.	-
2.1.1.	-
2.2.1.	-
2.3.1.	Animation
2.3.2.	Animation
2.3.3.	-
2.3.4.	-
2.3.5.	-
2.3.6.	Clickable Description
2.3.7.	Clickable Description
2.3.8.	Clickable Description
2.4.1.	-
2.4.2.	Clickable Description
2.4.3.	Clickable Description
2.5.1.	-
2.5.2.	-
2.5.3.	1 * 2 choice quiz
2.5.4.	1 * 2 choice quiz
2.5.5.	1 * 2 choice quiz
2.5.6.	1 * 2 choice quiz
2.5.7.	-
2.5.8.	-
2.5.9.	1 * 3 choice quiz
2.5.10.	1 * 3 choice quiz
2.5.11.	1 * 3 choice quiz
2.5.12.	-
2.5.13.	1 * 3 choice quiz
2.5.14.	1 * 3 choice quiz
2.5.15.	-
2.5.16.	-
2.6.1.	-
2.6.2.	1 * 3 choice quiz
2.6.3.	Clickable Animation
2.7.1.	-
2.7.2.	-
2.7.3.	-
2.7.4.	1 * 2 choice quiz
2.8.1.	-
2.9.1.	Enter Number Test
2.9.2.	-
2.9.3.	-
2.10.1.	-
2.10.2.	-
2.10.3.	1 * 3 choice quiz
2.10.4.	1 * 3 choice quiz
2.10.5.	-
2.10.6.	1 * 3 choice quiz
2.10.7.	-
2.10.8.	1 * 3 choice quiz
2.11.1.	-
2.11.2.	1 * 3 choice quiz
2.12.1.	1 * 2 choice quiz
2.12.2.	-
2.12.3.	-
2.12.4.	1 * 3 choice quiz
3.1.1.	-
3.1.2.	-
3.2.1.	-
3.2.2.	Clickable Description
3.3.1.	-
3.3.2.	-
3.3.3.	-
3.3.4.	-
3.3.5.	2 * 3 choice quiz
3.3.6.	-
3.3.7.	-
3.3.8.	-
3.3.9.	1 * 3 choice quiz
3.3.10.	-
3.4.1.	-
3.4.2.	1 * 3 choice quiz
3.5.1.	-
3.5.2.	-
3.5.3.	-
3.5.4.	1 * 3 choice quiz
3.5.5.	-
3.5.6.	-
3.5.7.	1 * 3 choice quiz
3.6.1.	-
3.6.2.	-
3.6.3.	1 * 3 choice quiz
3.7.1.	-
3.7.2.	1 * 3 choice quiz
3.7.3.	-

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3.7.4.	1 * 3 choice quiz
3.7.5.	-
3.7.6.	1 * 3 choice quiz
4.1.1.	-
4.1.2.	-
4.1.3.	-
4.1.4.	-
4.2.1.	-
4.2.2.	-
4.2.3.	-
4.2.4.	-
4.2.5.	-
4.2.6.	1 * 3 choice quiz
4.3.1.	-
4.3.2.	-
4.3.3.	-
4.3.4.	-
4.3.5.	-
4.3.6.	-
4.3.7.	1 * 3 choice quiz
4.3.8.	1 * 3 choice quiz
4.3.9.	1 * 3 choice quiz
4.3.10.	-
4.3.11.	-
4.3.12.	-
4.3.13.	1 * 3 choice quiz
4.3.14.	-
4.3.15.	-
4.3.16.	-
4.3.17.	-
4.3.18.	-
4.3.19.	-
4.3.20.	-
4.3.21.	-
4.3.22.	-
4.3.23.	-
4.3.24.	-
4.3.25.	-
4.3.26.	-
4.3.27.	-
4.3.28.	-
4.3.29.	-
4.3.30.	-
4.3.31.	-
4.3.32.	-
4.3.33.	-
4.3.34.	-
4.3.35.	-
4.4.1.	-
4.4.2.	1 * 3 choice quiz
4.4.3.	-
4.4.4.	1 * 3 choice quiz
4.4.5.	-
4.4.6.	1 * 3 choice quiz
4.4.7.	-
4.4.8.	1 * 3 choice quiz
4.4.9.	-
4.4.10.	1 * 3 choice quiz
4.4.11.	-
4.4.12.	1 * 3 choice quiz
4.5.1.	-
4.5.2.	Clickable Animation
5.1.1.	-
5.2.1.	-
5.3.1.	-
5.3.2.	-
5.3.3.	-
5.4.1.	-
5.4.2.	-
5.4.3.	1 * 3 choice quiz
5.4.4.	-
5.4.5.	-
5.4.6.	1 * 3 option drag quiz
5.4.7.	-
5.4.8.	-
5.4.9.	1 * 3 option drag quiz
5.5.1.	-
5.5.2.	-
5.5.3.	-
5.5.4.	1 * 3 choice quiz
5.5.5.	-
5.5.6.	1 * 3 choice quiz
5.5.7.	-
5.5.8.	1 * 3 choice quiz
5.5.9.	-
5.5.10.	1 * 3 choice quiz
5.5.11.	-
5.5.12.	Clickable Animation
5.6.1.	-
5.6.2.	-
5.7.1.	Clickable Animation
5.8.1.	Clickable Description
5.8.2.	-
5.9.1.	-
5.9.2.	-
5.9.3.	-
5.9.4.	6 * 6 option drag quiz
5.10.1.	-
5.10.2.	-
5.11.1.	2 * 3 choice quiz
5.11.2.	-
5.12.1.	2 * 2 option drag quiz
6.1.1.	-
6.1.2.	-
6.1.3.	Enter Number Test
6.1.4.	Clickable Animation
6.2.1.	-
6.2.2.	-
6.2.3.	3 * 3 choice quiz
6.2.4.	-
6.2.5.	-
6.2.6.	3 * 3 choice quiz
6.2.7.	-
6.2.8.	-
6.3.1.	-
6.3.2.	-
6.3.3.	1 * 2 choice quiz
6.3.4.	1 * 2 choice quiz
6.3.5.	1 * 2 choice quiz
6.3.6.	1 * 3 choice quiz
6.3.7.	1 * 3 choice quiz
6.3.8.	-
6.3.9.	1 * 3 choice quiz
6.3.10.	Clickable Description
6.3.11.	Clickable Description
6.4.1.	-
6.4.2.	-
6.4.3.	-
6.4.4.	1 * 3 choice quiz
6.5.1.	Clickable Description
6.6.1.	-
6.6.2.	-
6.6.3.	-
6.6.4.	-
6.7.1.	-
6.7.2.	-
6.7.3.	-
6.7.4.	1 * 3 choice quiz
6.8.1.	2 * 3 choice quiz
6.8.2.	-
6.9.1.	-
6.9.2.	-
6.9.3.	1 * 3 choice quiz
6.9.4.	1 * 3 choice quiz
6.9.5.	-
6.9.6.	1 * 3 choice quiz
6.9.7.	-
6.9.8.	1 * 3 choice quiz
6.9.9.	-
6.10.1.	-
6.10.2.	1 * 3 choice quiz
6.11.1.	-
6.11.2.	-
6.11.3.	-
6.12.1.	-
6.12.2.	-
6.12.3.	-
6.12.4.	3 * 3 choice quiz
6.12.5.	-
6.13.1.	-
6.13.2.	-
6.13.3.	-
6.13.4.	-
6.13.5.	-
6.13.6.	-
6.13.7.	-
6.13.8.	-
6.13.9.	1 * 3 choice quiz

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This research was supported, in part, by a grant from the National Science Foundation, NSF-CCLI 0088947.

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