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A Study of Students' Perceptions of Computer-Based Instruction in Introductory Thermodynamics Courses

M.P. Sharma[1], Edward E. Anderson[2], and Roman Taraban[3]

[1]Department of Chemical and Petroleum Engineering
University of Wyoming
Laramie, WY 82071-3295
sharma@uwyo.edu

[2]Department of Mechanical Engineering
Texas Tech University
Lubbock, TX 79409-1021
edanderson@ttu.edu

[3]Department of Psychology
Texas Tech University
Lubbock, TX 79409-2051
roman.taraban@ttu.edu

Abstract

While education processes in all disciplines are experiencing some paradigm shifts with the recent advent and rapid advances made in the technology of designing, developing, and delivering Computer-Based-Instruction (CBI), engineering education, in particular, is entering a new and challenging phase. One of our biggest challenges is integrating CBI technologies (CD-ROM, World Wide Web/Internet, Online Synchronous/Asynchronous, Compressed Video, and hybrids of these tools) and assessing the effectiveness of their integration on teaching and learning by students in terms of depth of knowledge learned, dexterity/skill of problem solving, motivation/attitude, achievement, and retention of knowledge. Researchers of teaching and learning phenomena and processes, and educational psychologists, are investigating these phenomena based on different perspectives, theories, and hypotheses. Supported by a grant from the National Science Foundation, the authors of this paper have developed computer-based-instruction modules for an introductory thermodynamics course that incorporate active learning exercises within them. These techniques include interactive exercises, immediate feedback, graphical modeling, physical world simulation, and dynamic animations and exploration. The CBI modules employed interactive multimedia modules (CD-ROM and Online Teaching-Learning-

Testing OTLT methods) that were meant to improve students' integrative understanding of basic concepts and to emphasize problem solving. The authors are assessing the integration of the modules into the course. This has been done through formative evaluations in which we collected data on students' performance and perceptions over several semesters. These data were collected to investigate the impact of these changes on students' learning, as well as to gain insight into students' experiences and perceptions. Interviews were conducted with the students to garner feedback about the integration of CBI modules and students' perceptions of the modules' effectiveness for learning and achievement in the course. This paper describes interview data and outlines a tentative analysis of the data. The data suggested that students had mixed experiences and perceptions because (a) they found the pedagogical approach of requiring the use of these CBI modules to be an additional time burden (too time consuming), (b) there were inadequacies in integrating and reinforcing the material, and (c) because of students' own perceptions and beliefs about what efficient learning should be.

Introduction

With the advent and rapid advances in Instructional Technologies (IT) - like CD-ROM, Web, Internet, Animations, Hot Button tools - engineering education is entering a new and challenging age. One of our biggest challenges is integrating Computer-Based-Instructional (CBI) technologies into courses and curricula, and assessing the outcome of these improvement and enhancement efforts for engineering students.

As we observed in one of our earlier research papers[1], students' perceptions of various aspects of teaching and learning in a course are an important parameter that distinguishes good teaching from bad teaching and results in learning that may be characterized as being deep, engaging, and reflective, versus superficial, passive, and mostly memorization. For example, this latter condition arises when workload is too high. Therefore, the teacher faces a dilemma. On the one hand, he or she must demand enough of students, but on the other this will only be effective, and be perceived as effective, if students have sufficient resources to rise to those demands and to fulfill them in a deep fashion. These general instructional issues apply to the development and employment of computer-based and multi-media instructional materials. Students' perceptions play an important role in that and are an indicator of the effectiveness of the instruction that we design and deliver. Some instructors and educators may feel uncomfortable with the concept of "student self-reflection", because of the notion that we are here to teach students, not to ask them how they "feel" about the course. We prefer hard numbers and are more accustomed to quantitative assessment methods. But the utility of qualitative methods (interview assessment, portfolio assessment) of assessment has been demonstrated in many science, mathematics, and engineering courses[2].

The ability to effectively integrate new learning and teaching (instructional) technology tools and paradigms into engineering pedagogy is essential for continuous improvement of engineering pedagogy and curriculum. With a grant from the NSF, faculty at the University of Wyoming and Texas Tech University are implementing several innovative methods aimed at improving the intellectual/conceptual understanding and problem-solving skills of students in introductory thermodynamics engineering courses. The effort is focused on using new computer based learning technologies as a mechanism to integrate and emphasize the use of active learning methods based on specially developed CBI modules (CD-ROM) and on-line Teaching-Learning-Testing (OTLT) tools (online problem solutions, quizzing and testing). The project includes (a) the design and development of these pedagogical modules employing innovative uses of current Instructional Technologies (IT) to enhance student learning, and (b) development of innovative assessment techniques to evaluate the effectiveness and improvements in the knowledge gained and skills acquired by the students. The details of the design and development of the CBI modules and on-line teaching-learning-testing (OTLT) methods are described elsewhere by the authors of this paper[3, 4]. One specific example is of the introduction of new graphical and simulation animation of the performance and working of engineering systems/devices and a hot button approach of active interaction in the learning of difficult concepts. The objective is to explore challenging thermodynamic concepts and phenomena through the use of physically realistic animations and active learning tools. The combination of such activities is inherently synergistic and integrative because students are required to use these tools with other tools of learning being employed (textbook, lectures, hands-on homework problem solving). By manipulating animations, answering multiple choice questions, receiving immediate feedback on their selected answers, and exploring what-if scenarios, students are able to visualize concepts, relationships, problem-solving approaches, and practical applications and their significance, which would not be possible in more traditional learning contexts.

Most of these new technology-based changes, modules, and methods are based on a common-sense assumption that this kind of integrated teaching is beneficial to student learning and will lead to a more comprehensive and integrated understanding of the materials to be learned in the course. Some educators have started referring to today's learners as " The Nintendo Generation"[3]. Reisman and Carr[5] concluded that students learn 20% of the material taught by hearing, 40% by seeing and hearing, and 75% by seeing, hearing, and doing. Highly interactive, well-designed computer-based-instruction (CBI) modules and online Teaching-Learning-Testing (OTLT) thus offer the possibility of achieving the 75% goal. Renshaw, Reibel, et al.[6] state "students unanimously preferred modules that incorporated animations and interactive design tools." Others[7, 8, 9, 10] have reported similar findings in several engineering fields and for other topics. Since it seems that students prefer interactive multimedia modules and retain more material presented in this way, the goal of any CBI effort should be to use engaging interactive material rather than static material. While this assumption may be accepted, we sought to empirically explore the effects that these CBI materials had on students' learning. By taking this approach we did not take for granted that the integration of CBI would result in improved student learning. Rather, (a) we probed for evidence that CBI-based enhancement in integrated learning had indeed occurred and (b) we examined students' experiences and perceptions as they engaged in CBI activities. A sample of thematic questions that motivated this research includes:

- In the employment and integration of CBI methods, what are the issues and factors that promote, as well as hinder, students learning?
- What does integration of CBI mean to engineering students?
- In what ways does integration take place through the course syllabus and topics?

- Where are the rough spots (unsuccessful spots) of integration of CBI within the course?
- Where are the successful spots (areas) of implementation and integration?
- What are the characteristics of successful spots and unsuccessful spots?

This paper describes the interview methodology and process, and presents the observations and conclusions about the perceptions of students that emerged from the data. As we engaged in the process of analysis, various themes emerged based on what students told us during the interviews. The dominant themes relating to employment and integration of CBI tools are discussed along with examples of students' responses. The data and results reported here are fundamentally qualitative in nature. We used a methodology of student interview that was modeled on the basis of a framework discussed by McKenna, McMartin et al.[11] and Huberman and Miles[12]. The methodology focused on revealing students' experiences and perceptions of the course and of the various teaching tools that were employed in the course. The methodology can be applied to other qualitative research studies in assessment of engineering courses.

Assessment Methods

As discussed in one of our earlier papers[3], assessment of learning and educational methods and materials is commonly done by (a) comparing student performance (normally, final course or other grades) of sections or groups using the materials to sections that didn't use the materials, (b) measuring time-on-task, and (c) student satisfaction survey. Although such measures give considerable insight into global performance, they don't measure things such as effectiveness of individual activities, change in student knowledge base, and change in their perception of knowledge gained, student attitudes towards course expectations, learning styles, and time requirements. These may be significant measures for instructional development purposes. However, students' perceptions of CBI modules and knowledge gained also provide meaningful data because they provides insights that other assessment tools cannot for making improvements in re-designing CBI exercises. Hence, it is important to tailor assessment materials that contribute to the accomplishment of this latter goal as well. Several assessment methods are being employed in this project that address various considerations. They include attitudinal assessment, knowledge assessment, and usage assessment through (a) written questionnaires, and (b) computer records created over the course of a semester that automatically record students' interactions with on-line problem sets accessed over the Internet[1]. This paper discusses the methodology and procedure of "Assessment by Interview." Interviews are face-to-face meetings between people that give the interviewer a chance to expand on questions asked or probe answers that the interviewee gives.

Procedure and Methodology of the Two-dimensional Interpretive Method Used

Our interviews were conducted with approximately 95 students over three semesters (Spring 2002, Summer 2002, Fall 2002) of teaching the course. Each semester, all the students in sections taught by one of the authors (MP) were invited to participate in the project. Students signed up for 15-minute slots. Participation was voluntary. Based on the total number of students enrolled, the response rate was approximately 85%. The students interviewed represented a diverse population with respect to gender, class standing (sophomore, junior, senior) and grade point average (GPA). Of the students interviewed, 15% were seniors, 75% juniors, and 10% sophomores. Approximately 85% of the students interviewed were male and 15% female. The students also covered a range of ability as measured by their GPA with 1.8 being the lowest and 4.0 the highest.

A sample of questions used for the interview is shown in Table 1. These questions were designed to elicit data from students about their experiences and perceptions within the course. The interviews were conducted over a period of three weeks at the end of each semester. Over the length of the project, questions were rephrased and rearranged. New and more relevant questions were added, and ineffective questions were dropped.

After completing the interviews a qualitative analysis was performed. The qualitative analysis approach (and data collection) approximately followed the model of Huberman and Miles[12]. This model influenced the design and selection of the research questions, sample selection, methodologies, and analysis. A very important aspect of the model is the concept of an ongoing process of analysis that occurs during design, planning, and data collection, and continues after data collection has been completed, making the process inherently iterative. This provides a characteristic mechanism of building upon the researchers' observations during data collection, data reduction, and observations of the interviews. First, a simple "Theme Labeling/Tagging/Coding" scheme was developed[13] that allowed categorizing student responses for initial analysis. A few examples of the tagging/coding scheme are provided in Table 2. All of the interviewee's responses were labeled based on the categories developed. Some of the responses fell into more than one category. In such cases the response was assigned to more than one label. Responses that did not fall under the original categories were not assigned to any codes. These responses were deemed unrelated to the research questions.

Based on the objectives and goals of the course (discussed below in a separate section), the analysis was focused on the broad questions; "How do students talk about the different tools/modules and course topics?", "What factors and activities in the course contribute to an improved, more enhanced understanding?" and "How do students' beliefs about the course contents/objectives, tools used, and the nature of learning affect their conceptual understanding and problem-solving skills?" A subset of tagged responses was selected that most closely aligned with these broad research questions.

Some of the interview responses and data had many dimensions. Responses were reviewed carefully to identify new emergent themes. Research questions were refined based on this review, and new tagging schemes were created that better represented the category of the question. Specific comments made by students regarding course enhancement and knowledge integration were identified, analyzed, and categorized.

In summary, the methodology was built on the following steps: start with a broad tagging scheme in order to sort the data; focus on a subset of tags/codes that elicit and relate to a broad research question (such as "What factors and activities in the course contribute to an improved, more enhanced understanding?"); carefully review these codes to identify dominant themes in the interview data; from these dominant themes develop and capture the main ideas/perceptions of students relating to the issue of enhancement of understanding, skill, and achievement of the goals for the CBI tools employed. Thus by creating the specific categories in the tagging/coding scheme, we have classified the interview data according to an interpretative framework. The following section presents the results and discussion.

Course Objectives and Goals

In the field of engineering education and among students and alumni of engineering, thermodynamics courses carry a reputation of being frustrating, confusing, and demanding. At best, most consider it difficult to acquire mastery of concepts, principles, and procedures of thermodynamics. Many accomplished teachers of engineering thermodynamics have experimented and researched on novel approaches for teaching thermodynamics more effectively[4]. The adoption of new CBI based pedagogical methods and approaches for teaching thermodynamics leads to concerns with existing assessment methodologies to evaluate teaching and learning. There is a variety of opinions, and skepticism and resistance to change and enthusiasm for something that is new. These views range from negative to positive. Several groups of researchers[14, 15, 16, 17, 18, 19, 20] have addressed these concerns in their research. Their papers provide a good resource base for researching and designing a modern and appropriate assessment plan for this course. Based on a review of published literature, it was conjectured that online engineering thermodynamics materials could help in improving engineering and science education. They can provide a powerful motivating context for learning fundamental and applied principles, and could better motivate students' interest in learning.

The Course Learning Objectives were divided into units with each unit basically representing learning goals of each chapter covered from the textbook. The following learning objectives were identified for the design and development of the CBI materials: Develop an understanding of basic thermodynamic concepts and principles including laws of thermodynamics, energy and its transformations, and system/control volume formulations and cycle analysis, with emphasis on theory and applications. The materials would also provide experience with SI units, the English unit system, computer-based problems, and some elements of design.

Materials and Tools

The textbook for the course was *Thermodynamics: An Engineering Approach* by Cengel and Boles[21]. Accompanying the textbook was a CD with modules that incorporated active learning exercises, including interactive exercises with immediate feedback, graphical modeling, physical world simulations, and explorations within them. Computer-based homework problems were written by the second author of this paper for the first ten chapters of this textbook, and were made available to students over the World Wide Web. The questions were based on material in the textbook, lectures, and the CD that accompanied the textbook. Each time a student chose a problem set for a chapter subsection, he or she received a problem set consisting of five questions. If there were multiple versions of the problem set, the system randomly selected one of the sets for the student. The questions contained randomly generated parameters in their statements, so it was unlikely that students received identical problem sets. The questions were divided to fall in the following categories: Interactive Questions, Short Response Interactions, Coaching, and Experimental Simulations[3].

Analysis, Results and Discussion

A scheme of categories and subcategories in our interpretive process and classification framework are shown in Table 3. This type of labeling and identification became the basis for interpreting the data. The notions and arguments of McKenna, McMartin. et al.[11] suggested that assessment of teaching-learning improvement and enhancement should be considered from a pedagogical as well as an epistemological point of view. To understand the basis for this two-dimensional analysis, the following paragraphs were paraphrased directly from their study:

"…… the pedagogical point of view takes into account issues regarding the curriculum such as teaching style, classroom activities, course sequencing, etc. Most (improvement and) integration reform efforts focus on issues of pedagogy in terms of affecting change through altering the curriculum. While pedagogical change is essential and inherent in any reform effort, our interview data suggests that there are complementary, and equally important, epistemological issues to consider. Epistemological issues refer to students' perceptions about engineering and their beliefs about the nature of learning and problem solving. Based on our data, the epistemology of integration can be defined as the students' understanding of the nature of integrated knowledge. The epistemological point of view takes into account how students perceive the curriculum (or course)…... Our data suggests that students hold strong beliefs about the nature of the disciplines (or courses) and these beliefs interact with the curriculum (or a course improvement efforts/tools) and pedagogical reform efforts."………."For example, pedagogical changes to the curriculum are external to the student and these factors can be characterized independent of the individual student. Changes such as revising course content and structure, enhancing communication, implementing design projects are most often done at the departmental or faculty level. Epistemological issues, on the other hand, relate directly to what the student thinks, perceives, and understands. These issues are intrinsically internal to the extent that they can not be characterized without obtaining feedback from the individual. We view these two sides of our framework as complementary data sources. Students' epistemological comments tell us about the effect of the pedagogical reforms, and pedagogical reforms theoretically affect students understanding and beliefs. Both sides of the framework are therefore necessary to provide a comprehensive understanding of any course or curriculum reform."

In Table 3, the label/code of 'pedagogy' captures student comments regarding the course topics and objectives and classroom issues. Data within the pedagogical framework relate to issues external to the student. In contrast, the codes under 'epistemological' relate to students' beliefs and perceptions. These comments relate more to an individual student's internal cognitive mechanisms. Like McKenna, McMartin. et al.[11], we see a "distinction between what happens *to* the student and what is thought *by* the student." The literature typically argues that integration of CBI and OTLT in a course inherently "helps students to visualize and understand more effectively. These enhancements can help students in conceptual understanding of knowledge and problem solving skills [22]." Quantitative and qualitative data are needed to validate this notion and theory.

An example of student comments for one category of tags, "Factors that help learning," is provided in Table 4. These responses fell under the pedagogical side of the issues. The comments addressed the topic of employing CBI and OTLT tools and made suggestions to improve the learning experience. A common suggestion that emerged from the data was to provide learning activities "that facilitate students in solving their assigned homework problems" without consuming a lot of time on their part. The data indicated that this was helpful because students perceived that it provided them the opportunity to be efficient if the instructor did, in advance, an example problem much like the assigned homework problem.

Using this approach, a qualitative analysis could be performed by sorting the data to determine the total number of comments in each category. This approach can also afford a graphical inspection of the data and an approximate tally of responses[11]. That has not been done for this project yet. One needs to be mindful and careful not to impose rigorous statistical significance to data that is inherently qualitative in nature. Of the students interviewed, 80% expressed experiencing some sort of problem (to varying degrees) in the use of the CD-ROM. The theme "doing homework like example problems in the class" received the most comments, approximately 90%.

Students' response data also gave insight into students' perception about the nature of the course. Table 4 lists responses under the epistemological category "Perceptions about Thermodynamics." These comments suggested that students believed that thermodynamics was a difficult and frustrating course. By default, these comments suggested something about the effect the course and teaching tools had on student understanding. For example, if the goal of CBI integration was to provide relevance, these comments suggested that this goal was not being achieved effectively, perhaps because of frustrations related with technical difficulties in using the CD-ROM. Also, these comments served as a guide for improving the CBI modules in the re-designing phase. These comments also revealed students' underlying understanding about the nature of thermodynamics. This helped us to identify 'pedagogical gaps' that affected students' perceptions. It can be argued that these perceptions are a direct result of students' background and classroom experiences with different pedagogical methods and tools. These perceptions interact with students' learning experiences and ultimately affect the success of any pedagogical changes that we try to employ. Therefore, the epistemological aspect revealed students' perceptions and beliefs, providing cues for the overall direction and specific issues to be attended to in the re-designing phase of these modules and tools.

Based on responses to questions related to students' computer background, it was observed that most of the participants felt they had good to very good backgrounds. The high level of computer ownership suggested that students had made a commitment to the new technologies, and that they possessed sufficient computer resources and knowledge for computer-based instruction.

Based on responses to questions related to workload and study time, the vast majority of students (80%) felt that the workload was reasonable (not too high, not too low). No one reported that it was too low. About 20% reported that it was "high" to "too high." Those who reported it to be "too high"/"high" attributed the reason to CBI and Internet exercises, and wished that these elements were not in the course or were present with less importance attached to them.

Based on responses to questions related to on-line homework, students felt that the problems were not too difficult, and that the problems could be completed within a reasonable amount of time. The majority of students (80%) felt some questions were very interesting and helped them understand concepts, but some questions had wrong answers. The majority (90%) perception was that the questions did not help them in their problem solving skills as much as the problems helped them in looking at the concepts.

Based on responses to questions related to on-line homework versus CD versus paper-and-pencil homework, by far most students (90%) felt that the most effective learning resulted when they did paper-pencil homework problems. The CD-ROM exercises were perceived to be least effective, even though, from our perceptions, the CD had high-quality activities, provided immediate feedback, and included simulations and opportunities to explore phenomena. These data support the general claim that availability of instructional materials is a necessary factor but not sufficient in itself to motivate students to benefit from the materials. Students completed the on-line homework because they received points for doing so. Many students completed the homework without paying much attention to it (just mechanically).

Based on responses to questions related to Distribution of Homework Times, the majority of students reported that they invested the biggest chunk of their time on the paper-pencil homework. They felt that the CD-ROM took up the next highest chunk of their time, but it was because of resolving technical problems in using the CD.

Some questions and responses related to tests (online versus paper-pencil tests). Out of a total of four tests, two were given online, and two in class (paper-pencil). In the beginning, a vast majority of students (95%) expressed negative feelings about on-line tests. By the end of the semester, only a few (10%) had reservations about on-line tests. In one semester, the students were give the option to take the final examination either in-class or on-line. Out of a class of 33 students, only three took the in-class test. By this time, they had the experience of taking at least one on-line and one in-class test in this course.

Based on responses on questions related to the most effective learning tool (textbook, CD-ROM materials, online materials, lecture notes, paper-pencil homework), the largest number felt it was the textbook, followed by doing paper-pencil homework, lecture notes and working in study groups. The CD-ROM and online materials were on the margins. In general, the most valuable resource for these students, as reflected in their perceptions was the textbook. Information at websites played a minor role.

Concluding Summary

CBI and online engineering courses present complex challenges for delivering education compared to traditional classroom-based courses. The development, implementation, evaluation, enhancement, and new implementation of components and modules of any CBI course is a continuing process of evolution towards perfection, especially in view of the fast changing Web tools and technologies. This online thermodynamics course is no exception.

This paper describes an interview project conducted for studying the perceptions of students about the improvements and enhancements in the teaching-learning effectiveness of a course on introductory thermodynamics in which a variety of computer-based-instructional tools were employed and integrated into the course (under a project funded by NSF). Approximately 95 interviews were conducted over a period of 3 semesters of teaching this course. Using a methodology of analyzing and interpreting qualitative data[11, 12] the responses and comments were categorized along two dimensions: pedagogical issues and epistemological issues for interpreting and drawing conclusions on students' perceptions. This dual framework of pedagogical and epistemological issues allowed a comprehensive analysis of the data in order to study the impact of employing and integrating CBI modules and methods. It is hoped that the general conclusions and methodology discussed here will help us understand the nature of student learning and inform us of the directions of our next efforts to improve the teaching-learning of engineering courses.

In this study we showed how interview response data could be used to establish or refute the hypothesis that "use and integration of instructional technologies (CBI and OTLT modules and methods) into an engineering course would improve the effectiveness of students' learning (conceptual knowledge and operational skills)."

We, as instructors, face challenges in intuiting, conceptualizing, designing, and deploying new and emerging technology-based tools, modules, and methods for improving teaching-learning effectiveness because these efforts must result in more effective teaching and learning paradigms, but also must be perceived as effective (more effective) by students. Only then can we release the natural motivational energy in students to rise to the demands of new ways of learning. Computer materials must be developed and tested in ways that assure that they engage students in a perceptual fashion in addition to other manners.

The most successful students in the CBI-based and online thermodynamics course seem to be those who are more self-motivated and self-directed, and who have a preference for self-paced learning rather than directed learning. The development of CBI modules and online components and their integration into teaching need a new mindset and approach, and should not be planned with the "offline thinking hat" on.

CBI and online teaching create a different paradigm for analyzing curricular performance and assessment/evaluation of the effectiveness of these new teaching-learning technologies.

Future Work

We will continue to use these methods to monitor students' perceptions as we refine the existing materials, continue improving the interview technique and methods of analysis of interview data, and as we expand CBI and IT resources for teaching the thermodynamics course. Furthermore, the project leaves several very important issues to be explored and studied in the future:

- analysis of the interview data for differences along gender and grade (GPA) level. For example, perhaps there is a fundamental difference between how males and females perceive the course.
- use of the qualitative analysis software package NIVO (or EXCELL) that allows one to sort interview data along many dimensions and categories
- correlating students' learning styles (e.g. Myers-Briggs Type Indicator) and perceptions about the course.

Table 1: List of Interview Research Questions Asked

1. How is the semester going for you?
2. Your major? Senior/Junior/sophomore?
3. How many hours are you taking this semester?
4. With what rumors or perceptions (overheard) did you come to the class (difficult/easy)?
5. Your expected grade in this course?
6. Out of learning resources (textbook, lectures, lecture notes, web sites (eCompanion site, Engineering site, Texas Tech site, CD- ROM that came with the book, CD-ROM that I handed out) which one was most effective for your learning? Which one did you use most?
7. Are you a self-learner, group/team learner?
8. Did you read/study the book thoroughly or in a spotty manner (all pages, selected examples)?
9. Did you learn something new and worthwhile in this course? Name one or two things.
10. Most difficult topic in the course?
11. Easiest topic in the course?
12. Which chapter/topic did you like most? Which ones were most interesting to you?
13. What did you like most about the course (on teaching-learning)?
14. What did you dislike the most about the course?
15. Were the tests fair/unfair, tricky?
16. What would you suggest changing in the course (in teaching/testing)?
17. What could I have done to help you do better than you did?
18. What could you have done to do better than you did?
19. What type of learner are you? Have you taken the MBTI test?
20. Type of test you like (online, paper-pencil/in-class)?
21. Have taken any course on-line or a course that had significant online components?
22. Any grading-related issue or problem?
23. How do you feel about the textbook (how good, effective) ?
24. One or two things that come to your mind that you would characterize as best things in this course?
25. What was the most distracting thing about the course?
26. What is the single thing an instructor can do to motivate you?
27. Was there too much theory/principles/plug-chug?
28. Your thoughts on course load (homeworks etc)? fair/unfair?
29. One or two things that you learned that were new.
30. On-line homework solution site: Was it adequate for learning? How about the CD-ROM?
31. How confident are you about the knowledge that you have gained so far?
32. What kind of test taker are you?
33. Would you like to see more Internet, CBI components or less?
34. Did you have a teacher that changed your life/motivation?

35. Were you prepared for the class?
36. Any personal problem during the semester that interfered with your performance?
37. Coming in this course, what was your impression of the course?
38. Going out, what is your impression of the course?
39. Why were you in this section of the course?
40. Where will this course help you in your discipline?
41. Was my pace of covering the materials slow/fast/ok?
42. Were you comfortable asking questions?
43. Any frustrations/aggravations that you felt in the course?
44. Many students report that they understand the concepts, but can't solve the problems. Why do you think this happens?
45. What advice would you give faculty about how to improve this course?
46. Overall, how well do you think this course prepared you for upper division
47. engineering? Why?
48. Do you have any suggestions as to how we could make this course better?
49. Your expected grade in this course?

Notes:

a. These questions were classified/categorized according to different themes such as Background Information, Computer Experience, About The Thermodynamics Course, About The Tools Of Teaching-Learning Used In This Course (CD-ROM, online, textbook). Some categories have more than one question, or the same question phrased differently or asked from a different angle.

b. Not all the questions were administered to each student, but care was exercised in making sure that all the thematic categories were covered.

Table 2: Examples of Dominant Categories of Themes for Tagging Interview Responses

- Perceptions about Factors that Help Learning. Examples or descriptions of factors that help learning
- Perceptions about Nature of the Course
- Perceptions about Factors that Hinder Learning. Examples or descriptions of factors that hinder learning
- Suggestions students give to better integrate CBI tools and methods
- What students say constitutes good learning

Table 3: A Two-Dimensional Framework interpreting interview data[11]

Pedagogy
Factors that Help Learning

Epistemology
Perceptions about Thermodynamics

Table 4 Representative examples of student comments for two categories: "Factors that help learning" and "Perceptions about Thermodynamics"

Factors that Help Learning

- interest level, motivation
- discussing applications
- example problems done in the class by the instructor
- doing assigned homework (paper-pencil type) problems, group working

Perceptions about Thermodynamics

- textbook most helpful
- is difficult, engaging, but interesting
- is heavy on concept-driven and theoretical material, but has good practical applications
- requires students to shift their fundamental intuitions
- deals with ideal and practical problems
- deals with complex problems
- involves approximations/assumptions and/or empirical questions
- has design implications

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M. P. SHARMA
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, especially on the use of synchronous and asynchronous tools using Web technology.

EDWARD E. ANDERSON
Edward E. Anderson is Professor of Mechanical Engineering at Texas Tech University where he is also the Associate 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 B.S. and M.S. degrees in Mechanical Engineering from Iowa State University and Ph.D. degree from Purdue University.

ROMAN TARABAN
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).

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