The Impact of Course Resource Utilization upon Student Performance

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ABSTRACT: *Today's engineering students have many resources, like textbooks, study supplements, Internet websites, and CD-ROMs available to them. But, it is not clear if students use these resources, how they use them, and if their use improves student performance. This paper reports a study in which self-reported student activity logs were used to examine how students used a variety of supplementary study resources in the introductory thermodynamics course. Of the supplementary materials studied, students showed a preference for the textbook, interactive CD-ROM supplements, textbook homework problems, and on-line homework problems with instantaneous coaching feedback. Student use of these supplements was correlated with their performance on homework exercises, regularly scheduled examinations, and a final examination. These correlations indicate that students use the four aforementioned supplements in a mutually supportive manner and that they rely heavily upon homework exercises to understand the course material. The one supplement that correlated most strongly with student performance upon a comprehensive final examination was the online homework. This finding reaffirms that instantaneous, constructive performance feedback can and does improve student performance.*

1 INTRODUCTION

Engineering students of today have many learning resources available to them. They have syllabi, lecture notes, interactive homework problems, virtual labs, and other course resources available on the Internet. Textbooks come with tutorials, software, and web sites offering supplemental material and activities [1]. Professional societies and media publishers also offer course supplemental materials. In view of the number and variety of supplemental resources, several questions arise when implementing these resources: will students use the resources; how do they use them; and will use of these resources assist in learning the course material [2, 3]?

For the past three years, the authors have undertaken a project to (a) develop electronic supplementary course materials for an introductory thermodynamics course, (b) to assess the impact of these and other materials upon student performance, and (c) using the feedback from step (b) to refine and improve the electronic materials. These materials are described in Anderson et al. [4] and Taraban et al. [5] and may be accessed at www7.tltc.ttu.edu/thermotutorial or in Cengal and Boles [6]. During this project over 500 junior/senior engineering students at Texas Tech University (TTU) and the University of Wyoming (UWYO) have been involved. The activities and performance of these students were assessed with traditional examinations and homework, online examinations and homework, pre- and post-course surveys, data gathering embedded within the materials, "think-aloud" protocols, and activity logs. In this paper, we will examine the results of student activity logs and how these logs can be utilized to understand how students select their study materials and study behaviours, and how these choices impact their performance.

Student activity logs have been used for a variety of purposes [3, 7, 8, 10]. Faculty [3] at the United States Military Academy have used time surveys for civil engineering course management, evaluation, and course improvement. Over the long-term, the data provided Academy instructors with objective depictions of the temporal demands on students, and the survey data have been used to reduce course demands from about 120 minutes to about 60 minutes per lesson.

The activity logs used during this project asked the students to record the time they spent engaged in academic activities associated with the thermodynamics course. The data obtained from these activity logs were statistically examined and correlated with students' performance on homework and examinations to determine those resources and study methods that were most commonly used, and the impact of these resources upon student performance.

2 COURSE RESOURCES

The introductory thermodynamics course covers the basic concepts of thermodynamics, including thermodynamic properties, the first and the second laws, and the application of these concepts to basic thermodynamic systems. Materials used in the course included a textbook with homework problems, an interactive CD that was provided by the instructor, online homework problems, and 2.5 – 2.7 h of lecture each week. The CD incorporated active learning methods, and included interactive exercises, graphical modelling, and physical world simulations, as well as narrated content pages with illustrations, equations, graphs, and tables [4, 9]. A sample of the active learning exercises from this CD is shown in Figure 1.

Each online homework problem contained up to five multiple-choice or numerical answer questions representing the various steps in solving the problem. Most of these problems contained randomly selected problem parameters such that each student had to solve a unique problem. All of these problems provided feedback indicating the correct responses to coach the student in preparation for the textbook homework. The problem sets drew on a database of 670 questions. The online homework problems were made available over the Internet. Students were assigned homework problems from the textbook and online problems for part of their course grade. They also took in-class tests and a final examination for the majority of their course grade.

Students also had access to a course website that included a syllabus, abbreviated lecture notes, and links to online homework problems and other websites. These materials may be seen at www.eeanderson.pageout.net. The materials used were the same each semester, with only small changes and refinements determined by student performance from preceding semesters. An online sample final examination was used to consistently compare the student performance from one semester to the next.

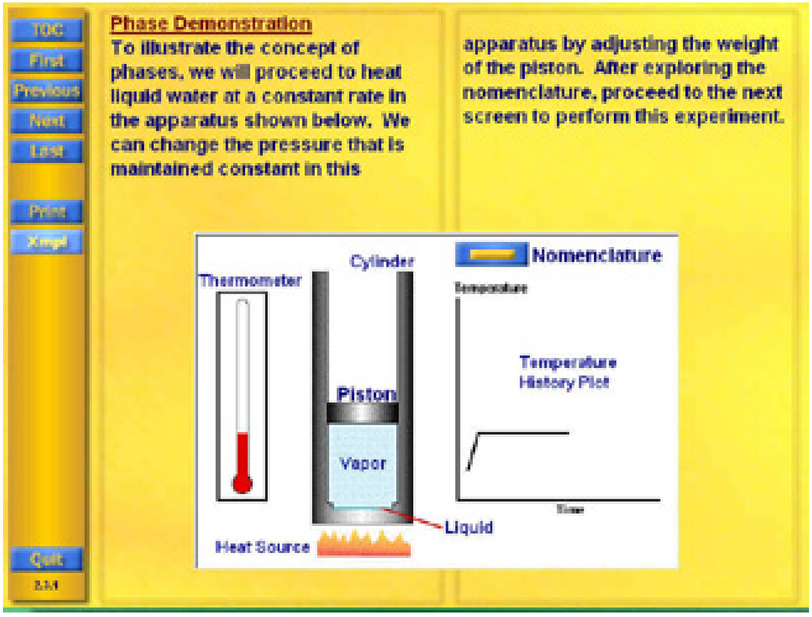

Figure 1 – Typical Interactive Exercise from the CD

3 PROCEDURE

Data were collected from six cohorts of students at the two universities over three semesters. Out of the 256 students who completed the courses, a total of 211 submitted activity logs, for a response rate of 82%. Over half of the respondents (52.5%) were juniors, and the remaining were either sophomores (27.0%) or seniors (20.5%). The mean number of engineering credits completed by these students was 36.46 hours (h) [standard deviation (*SD)* = 28.14], and the mean course load during the semester that the log was completed was 15.04 h (*SD* = 2.31).

The activities that the students were asked to account for were:

- **Lecture** – time spent attending class lecture or laboratory
- **Online** – time spent using online material and resources by browser access
- **Reviewing Lecture** – time spent reviewing lecture or laboratory notes
- **Reading Text** – time spent on first reading of the textbook
- **Reviewing Text** – time spent reviewing the textbook
- **Past Work** – time spent reviewing previous work including homework, quizzes, and past examinations
- **Rewriting –** time spent rewriting lecture, textbook, and other course notes
- **Supplemental** – time spent using other course resources not included in the course syllabus
- **CD** – time spent studying using the provided CD-ROM
- **Online Problems** – time spent doing the assigned online, interactive homework problems
- **Text Problems** – time spent doing the assigned homework problems in the textbook
- **Study Groups** – time spent studying in a student study group
- **Other** – time spent using some other study technique

These activity labels, which were developed in earlier pilot studies, were mutually exclusive and covered all possible student study behaviours. An activity log, which consisted of an instruction page detailing how participants were to use the log and the above set of labels and definitions, was constructed for the students to code their study-related activities. Students were asked to record the date, start time, end time, and activity they engaged in. The instructions explained that it was possible to use multiple resources simultaneously, and students were instructed to list all the resources they used at any given time. Background questions were included at the end of the log packet, including a question about the student's grade expectations for the course.

Each class was divided into student groups of 3-6 students depending upon the class size and each group was asked to maintain an activity log for one week. A different group was assigned to maintaining their activity log each week of the course. Each student in the class only completed one activity log during the semester. This sampling schema provided activity logs for both low-activity weeks as well as high-activity weeks when an examination or other major assessment was scheduled. The TTU student activity logs were also individually identified so that the data reported on each log could be correlated with their performance on other assessments including textbook homework, online homework, and examinations.

3 RESULTS AND DISCUSSION

The 211 respondents made a total of 1,505 log entries, or 7.13 entries on average per week. The overall response rate (82%) to the activity log and the average number of entries indicated that detailed activity logs could be used in thermodynamics to learn more about students' academic behaviors. Globally, the data revealed that mean class attendance per week was 2.07 h (*SD* = 1.05), and mean study time was 6.91 h (*SD* = 3.96). Although one might expect some exaggeration in self-reported data, the reasonableness of the class-attendance figure (based on a 2.5 – 2.7 hour maximum) suggests that this was not the case for the mean study statistics. If that were so, then these students exceeded the standard expectation of two hours of study per week for each course credit.

In the statistical analyses, significance was defined as a probability-value of $p \leq .05$, and marginal significance as $.10 > p > .05$. An analysis of the six cohorts of students using a 2 (school) by 3 (academic term) analysis of variance (ANOVA) showed significant variation in study time by school [TTU (*N* =

118): 7.78 h (*SD* = 4.06), UWYO (*N* = 93): 5.81 h (*SD* = 3.57); F (1, 205) = 11.63, $p <$ .002]; marginally significant variation by academic term [term 1 (*N* = 62): 5.86 h (*SD* = 4.06), term 2 (*N* = 56): 7.56 h (*SD* = 3.87), term 3 (*N* = 93): 7.22 h (*SD* = 3.86); F (2, 205) = 2.74, p =.067]; and a significant interaction between the two factors [F (2, 205) = 3.49, $p < .04$], the latter due largely to the greater variation across semesters at UWYO compared to TTU. We may attribute some of these differences to variation in student characteristics across cohorts of students (e.g., background knowledge, level of ability, level of interest), and part to the normal variation in course implementation from semester to semester.

In order to gain an understanding of how the students utilized the various study behaviours listed on the activity report, the data were first broken down into 84 mutually exclusive categories corresponding to unique study behaviours. Some of these behaviours were single behaviours like attending lecture while others were multiple behaviours like homework problems combined with study groups. These categories were then rank ordered for the entire sample of 211 and the largest singe cohort of 64. This rank ordering by total number of students using the various individual and combination study behaviours is shown in Figure 2. This figure only includes the single behaviour data since the frequency of usage by each of the several multiple behaviours was low compared to the frequencies of usage presented in Figure 2. The interested reader can find more information on multiple behaviours in Taraban, et al. [10].

The distribution of frequencies shown in Figure 2 reveal that these students predominantly preferred to study using some 5-7 main behaviours. The five most frequently reported behaviours were attending lecture, completing textbook problems, completing online problems, reading the textbook, and using the CD. The two newly developed resources that were added to the curriculum—the required online homework problems and reading assignments in the supplemental CD—were among the five resources that students used most. This indicated that these new elements were successfully incorporated into the curriculum, at least insofar as students using them. This may be a consequence of the fact that a small part of their course grade was determined by their usage of these materials. In fact, all of the five predominant study behaviours, except reading the textbook, were part of the overall course grade. Even reading the textbook is perceived by students as a necessary behaviour to earn the grade they desire in the course. These data then suggest that the majority of students will select and participate in those study behaviours that they perceive will directly impact their grades. Some students will participate in behaviours that don't directly contribute to their grades, like reviewing and study groups, but this number tends to be small.

Statistical analysis was conducted using the TTU sample displayed in Figure 2. This was necessary because it had the highest number of participants (N = 64) compared to the other samples (the next largest sample had 32 participants), and because students in this sample submitted their logs with their names. Thus, the correlation between learning resources and course grades could also be examined. Correlation analysis was applied to these data. This type of analysis was appropriate because it could reveal the strength and also the direction of the associations between learning resources. Nonparametric correlation analyses (i.e., calculation of Spearman's rho) were applied because the data did not follow normal-curve distributions; nonparametric techniques are recommended in this context [11, 12]. Finally, only the five most frequent behaviors were analyzed, simply because it did not make sense to form generalizations about behaviors that most students did not engage in (i.e., those with low frequencies in Figure 2), nor was it prudent from a statistical perspective to correlate data distributions in which most data points were zero.

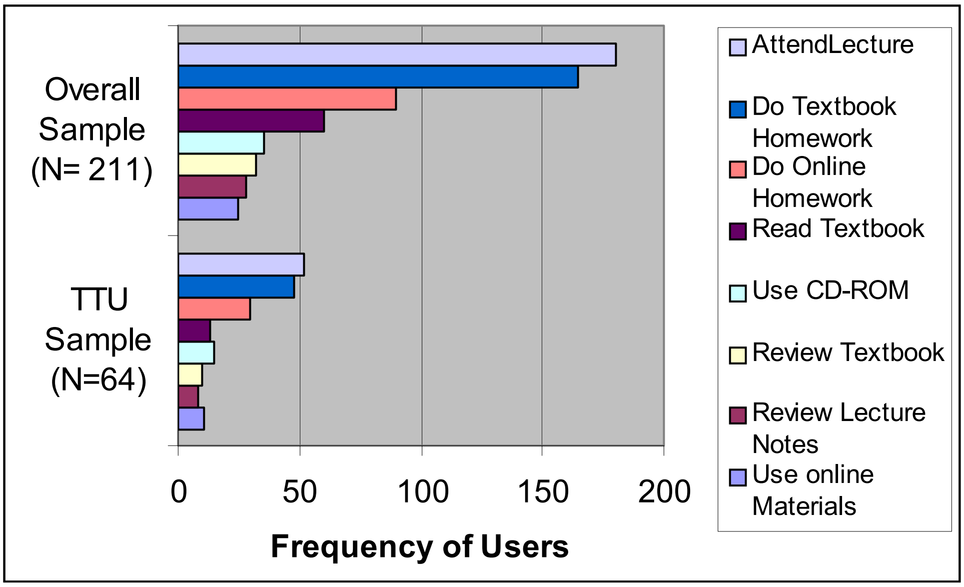

Figure 2 – Number of Students Reporting Various Study Behaviours

The results of this statistical study are summarized in Table 1. In this table, positive Spearman *rho*s in the table body indicate that the students were using the correlates in a mutually supportive manner, negative Spearman *rho*s indicate that the correlates were used in a compensatory manner, and the higher the magnitude of the Spearman *rho*s, the stronger the correlation. None of the negative correlations in these data reached statistical significance. For the most part, students were using these resources in a mutually supportive fashion, not in a compensatory manner. A strong association existed between solving textbook problems and solving online problems. Students who did relatively more of one did relatively more of the other. Solving online problems was positively and significantly correlated with using the CD. Relatively higher lecture attendance was also associated with relatively more use of the CD. All of which suggests "good student" behaviours.

Observe that the strongest correlations between study behaviours and rewards as determined by examination grades occurred with the online homework, not the text homework or text reading or other study behaviours. Traditionally, textbook materials are used in a passive manner, like a lecture, or individual and non-supportive manner, like student self-grading and limited feedback. This is particularly the case in large lecture sections. These data demonstrate that online homework, which in this project included instantaneous, quick, but effective, feedback, had more impact upon student performance in examinations than the other study behaviours.

Although the strongest correlation affecting student performance on the final examination was online homework problems, there were also strong correlations between solving online homework problems, solving textbook problems, and using the CD. Most likely, students used these several resources in conjunction, in order to achieve higher test and final scores. A positive, marginal correlation was also found between the time students spent solving text problems and their homework grade. These results suggest that students use homework to meet their performance objectives and then use other study resources and behaviours as needed to complement the homework assignments.

Table 1. TTU Sample Means (Standard Deviations) for Weekly Use of Learning Resources (in hours), Course Grades, and Spearman's *rho* for the Use of Resources and Grades

	B	C	D	E	F	G	H	Expected Grade
A. Lecture 1.94 h (1.06)	-.04	-.06	.13	**.25** $^{.056}$	.10	-.09	.17	-.04
B. Text Problems 2.17 h (1.99)		.10	**.35** $^{.007}$	.20	**.26** $^{.043}$	.17	.16	**.32** $^{.014}$
C. Reading Text 0.61 h (1.62)			.15	.11	-.11	-.11	.16	-.04
D. Online Problems 0.43 h (0.59)				**.31** $^{.015}$	.11	**.22** $^{.087}$	**.46** $^{.001}$	**.22** $^{.095}$
E. CD 0.37 h (0.74)					-.06	.16	.19	.11
F. Homework Grade 73.68 (20.26)						.09	.15	**.27** $^{.041}$
G. Test Average 85.99 (7.05)							**.44** $^{.001}$	**.24** $^{.061}$
H. Final Exam 79.35 (10.73)								**.30** $^{.022}$

Notes. Homework and test grades are on a 100-point scale. Statistics are based on $N = 60$, due to some participants not completing all elements in the analyses. *P*-values (two-tailed) for significant and marginally significant *rho*-values are shown as superscripts. Abridged from Taraban, et al. [10].

In this study, students spent less than 30 minutes (0.43 h) on average per week solving online homework, which the data suggest had the greatest impact upon their performance. One then suspects that meaningful, online homework with instantaneous feedback provides a good indicator of what students were learning. However, much of that learning may have been taking place through the coordinated use of other learning resources. Student efficiency (i.e., grade received for time spent) is strongly correlated with the online homework complemented by other learning resources.

Expected course grades were significantly correlated with the amount of time students reported working on textbook homework problems, and marginally with the time they spent working on online homework problems. This indicates an underlying belief among the students that academic effort leads to academic reward. It also suggests that students will invest the time required to achieve the grades they desire.

In this study, it was clear that one could not add additional requirements or resources without dropping existing requirements or resources because students were already meeting or exceeding the normal demands for study outside of class. Shifting emphasis to computer-based resources, like the more efficient online homework problems, requires a reduction of the number of assigned textbook problems. Getting students to spend more time with the CD-ROM would also require some modification to the structure and demands of the course [13], particularly time spent by students in lectures or reading a textbook. There is growing evidence that academic time is linked to academic behaviour [14]. This study supports the finding that a properly designed course provides students with sufficient time to complete valued activities. By selecting the most effective materials and tasks for students, instructors can devise more efficient learning possibilities for students, and can avoid overloading the curriculum [2].

4 CONCLUSIONS

In summary, this study, although limited to engineering students taking engineering fundamentals courses, was important in several ways. This study demonstrated the use of activity logs for measuring students' learning behaviors. The data resulted in significant statistical effects that were interpretable and that made sense. An analysis of the contribution of the dominant behaviors in the course suggested that not all student-learning behaviours were equally beneficial. The activity-log data were helpful in understanding the role of newly introduced curriculum elements—the online homework problems and the CD—in the context of the full set of learning resources available to the students. The time and frequency that students devoted to solving online homework problems, to solving textbook problems, and to related study activities, was found to be predictive of performance.

The strong correlations between examination performance and homework assignments that provide immediate and meaningful feedback suggest that this technique is an excellent candidate for improving learning efficiency thereby allowing students to learn the same material in less time. This technique can address the "overloaded curriculum" syndrome. Although this was accomplished with online homework problems in this study, it is expected that a similar gain in learning efficiency might be expected using the Keller instructional [15] and problem-based learning methods [16] since the Keller instructional method emphasises student feedback and problem-based learning places emphasis upon the problem to motivate learning.

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