Advances in Engineering Education

SPRING 2010

Improving Engineering Students' Cognitive and Affective Preparedness with a Pre-Instructional E-Learning Strategy

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ABSTRACT

During the 2006–2007 academic year, five faculty members from the College of Engineering at Boise State University initiated a curriculum augmentation project using new instructional technologies with the intention to help improve undergraduate engineering students' cognitive and affective preparedness for their classroom learning. The instructional technologies used in the project were a pre-instructional strategy and a self-paced e-learning method. The main question addressed in this project was: Will a pre-instructional e-learning strategy help engineering students cognitively and affectively prepare for their classroom learning? This paper is a report of the project, describing the analysis, design, and development of a multimedia e-learning module for an engineering curriculum, the implementation of the e-learning module as a pre-instructional strategy in two engineering courses, and the evaluation of the effectiveness of using the pre-instructional e-learning strategy on engineering students' cognitive and affective preparedness for classroom learning. It also provides a list of lessons learned from the project.

Keywords: e-learning, pre-instructional strategy, reusable learning objects.

I. INTRODUCTION

Despite the steady growth of overall enrollment in Science, Technology, Engineering, and Mathematics (STEM) education in the United States during the last three decades, enrollment in *engineering* programs in the nation still remains low [1, 2]. The lack of participation in engineering programs is attributed to various interrelated factors such as a lack of academic readiness in math, a failing experience during a critical stage of learning, misperceptions about an engineering career, a misunderstanding of the relationship between early engineering courses and a future engineering career, poor academic advisement, and a lack of social support [3–7]. These interrelated factors during students' early stage of learning in engineering call for special attention, but there is no single solution for this multifaceted problem. Resolution requires implementation of effective interventions in many dimensions of the educational system, such as institutional support, faculty development, and quality curriculum design.

From the *curriculum design* standpoint, effective instructional technologies should be integrated into the engineering curricula to help students become successful learners while they are preparing to pursue careers in engineering. With that in mind, a curriculum augmentation project was initiated in the College of Engineering at Boise State University during the 2006–2007 academic year. The project focused on improving cognitive and affective preparedness of undergraduate engineering students for classroom learning by implementing new instructional technologies including a pre-instructional strategy designed with reusable learning objects and a self-paced e-learning method. The following section provides the theoretical framework of this project.

II. PREPARING LEARNERS WITH INSTRUCTIONAL TECHNOLOGIES

A. The Importance of Cognitive and Affective Preparedness

Instruction is a set of systematically arranged events, designed to facilitate learning processes and to produce desired learning outcomes [8]. Ideally, when creating an instructional lesson or a curriculum, the instructional designer analyzes the types of instructional content based on targeted learning outcomes before designing the events of instruction [9]. Bloom and his colleagues defined three types (domains) of learning outcomes in their taxonomy of educational objectives—the cognitive domain (thinking), the affective domain (feeling), and the psychomotor domain (acting) [10, 11]. Since its development in the 1950s, Bloom's taxonomy has been adopted and elaborated by other instructional theorists and widely used in curriculum design [e.g., 12, 13], as it provides instructional designers with a comprehensive understanding about the types of learning outcomes produced by students, and it helps them develop and deliver instruction in a systematic manner. The three domains are intertwined such that positive outcomes in one domain often require support from others (see Figure 1). The cognitive domain deals with the development of intellectual abilities and skills, and the affective domain deals with the development of appreciation and motivation of learning [10, 11]; therefore, these two domains are particularly important in most subjects in higher education including engineering.

The cognitive and affective domains of learning outcomes are divided into several hierarchical levels, which are used to develop an instructional sequence from simple to more difficult and complex levels [13]. For example, the cognitive domain contains six hierarchical levels: knowledge, comprehension, application, analysis, synthesis, and evaluation [10], and the affective domain contains five hierarchical levels: receiving, responding, valuing, organization, and characterization by one's value system [11]. When students learn a new subject, they begin from lower levels of cognitive learning, knowledge and comprehension (i.e., knowing what it is), supported by receiving, responding, and valuing levels of affective learning (i.e., wanting to learn) before moving onto the higher, more complex levels of learning. In this early stage of learning, students also start developing their self-efficacy, which not only is a self-concept of one's cognitive abilities but also involves affective states influenced by the person's emotional experiences [14]. Therefore, the instructional events of an engineering curriculum would be most effective when they are designed to help students build cognitive and affective foundations to prepare for the subsequent learning processes. In other words, the learning environment should result in the student thinking, "I know I can do it, I'm confident that I will be successful, and I'll continue to learn it."

B. The Use of a Pre-Instructional Strategy

One such instructional method that is designed to facilitate the development of cognitive and affective preparedness for classroom learning is a pre-instructional strategy. Instructional events

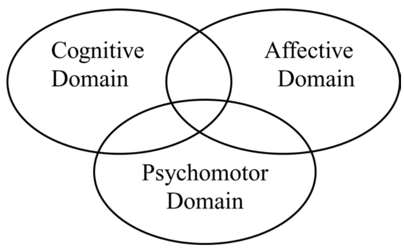

Figure 1: Three domains of learning outcomes (an interactive version of Figure 1 is available at the following URL - http://advances.asee.org/vol02/issue01/media/13/Figure1/engage.html***).***

are purposely arranged to maximize the learning outcomes. One may assume that purposely and systematically arranged instructional events occur only *inside* the classroom. However, the effectiveness of instruction can be improved by starting with a structured pre-instructional phase *outside* the classroom. An overview type of pre-instruction *alerts* learners of new content and *prepares* them to fully process new information during actual classroom instruction [15]. When teaching novice learners in the classroom, the pre-instructional overview is best designed for the knowledge and comprehension levels of the cognitive domain. Knowledge of facts, definitions of new concepts, and explanations of principles are necessary to improve their classroom learning. Successful completion of the pre-instructional overview can also improve the students' affective states of preparedness for classroom learning; that is, the students will enter the classroom feeling prepared, confident, and motivated to learn.

Compared to unstructured pre-instructional strategies such as giving reading assignments or post-instructional strategies such as a drill-and-practice type of homework, the benefits of using *structured pre-instruction* in engineering courses are promising. At the novice learner level, the pre-instructional strategy would be most effective if focused on an overview of the material at the lower levels of Bloom's taxonomy. Only a small number of research studies have been reported on the topic of the effects of structured pre-instructional strategies used in conjunction with, and prior to, traditional classroom teaching on learning improvement [16, 17]. One study [17] revealed that when students started utilizing a more intensive pre-laboratory activity in chemistry courses (from 20 minutes of unstructured preparation to one hour and 50 minutes of structured pre-lab instruction), a majority of them liked the new instructional structure, although some of them felt negatively about the increased workload before the lab. Forty-one percent of the students indicated that this new system might be suitable for difficult subjects.

C. The Use of Self-Paced E-Learning Designed with Reusable Learning Objects

Instructional methods shape the instructional content, and instructional media provide the delivery support. A pre-instructional strategy is an instructional method, and it can be effectively delivered via computer technology coupled with the Internet and the World Wide Web, which is known as *e-learning*. Presently, e-learning is deeply integrated into school curricula to motivate students and facilitate learning [18]. A growing body of literature exists in the community of engineering education that indicates the benefits of incorporating e-learning strategies in engineering education [e.g., 19–26]. In fact, leading academic organizations such as the Sloan Consortium advocate that several of the ABET engineering competencies can be augmented by online learning [19]. In contrast to one-to-many classroom learning, e-learning allows learners to adjust the pace, sequence, and type of media to better fit their learning behavior and needs. A number of studies have shown positive results when using self-paced computer-supported learning environments [e.g., 27, 28]. A tutorial, overview-type of pre-instructional e-learning allows self-paced learning during which students can increase confidence and better prepare for classroom learning.

One aspect to be considered when implementing a pre-instructional strategy through e-learning is to design the content with reusable multimedia learning objects to increase efficiency. A learning object (LO) is "any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning" [29]. Granularity is the core principle behind the design and use of LOs. Although LOs may come in different sizes, each LO is usually developed based on a single learning objective, and several LOs can be combined to form a larger scale instructional unit such as a unit or a complete course [30–32]. Benefits of designing e-learning content with the concept of LOs in mind include reusability, consistency, and cost effectiveness. LOs can be developed once and assembled differently to be used in multiple courses, resulting in reusable learning objects (RLOs) which improve consistency and cost-effectiveness in curriculum design.

D. Putting It All Together

Acknowledging the importance of developing engineering students' cognitive and affective preparedness for their classroom learning during their early learning processes and the benefits of using a pre-instructional e-learning strategy, the authors initiated a curriculum augmentation project by developing the described instructional technologies. The main goal of the project was to help engineering students improve their cognitive and affective preparedness for classroom learning. The project was partially supported by the National Science Foundation grant, *New Bachelor's Degree in Materials Science and Engineering*, awarded to Boise State University in 2006. Figure 2 illustrates the triadic relationship among the three elements considered in this project with the goal of producing successful learning.

The project was conducted through a systematic instructional development process called ADDIE, which is an acronym that refers to five major steps—analysis, design, development, implementation,

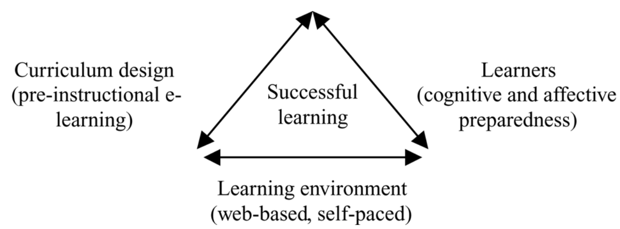

Figure 2: The triadic relationship among learners, curriculum design, and the learning environment (an interactive version of Figure 2 is available at the following URL - http://advances.asee.org/vol02/issue01/media/13/Figure2/engage.html).

and evaluation [33]. The following is a report of the project, describing the systematic instructional design principles that were followed, the actual multimedia e-learning module that was developed, and the evaluation results that were obtained.

III. DESIGN AND DEVELOPMENT OF E-LEARNING

A. Analyzing Learners

One of the early steps in systematic instructional development is to analyze learner characteristics. Of particular interest in this project was how different age groups of engineering students would use a multimedia e-learning module as a pre-instructional tool. Given the increase in non-traditional students participating in undergraduate programs in recent years [34], research that addresses differences in studying engineering as a function of age of the student is important for the enhancement of engineering education. This issue is particularly important for the four undergraduate engineering programs at Boise State University because of the high population of non-traditional students (more than 30% are older than 25). Boise State has approximately 750 undergraduate students enrolled in Civil Engineering, Electrical and Computer Engineering, Mechanical and Biomedical Engineering, and Materials Science and Engineering, and most of the engineering classrooms consist of a mixture of younger and older students. However, very little research has been conducted on the effect that age has on learning, especially e-learning, in STEM subjects at the undergraduate level. A small number of studies have shown that no significant differences exist in academic achievement or completion rates between traditional and non-traditional undergraduate students [e.g., 35–37]. However, in terms of computer use, older users report lower levels of confidence in using computers, compared to younger users [38, 39]. This aspect of age difference coincided with anecdotal evidence observed at Boise State that age is potentially an important factor that influences engineering students' overall behaviors and attitudes toward their learning. That is, non-traditional older students tend to take learning more seriously, but they typically have more demands on their time (e.g., families and work); hence, they try to be more efficient about how they prepare for class. However, younger and older students also have different attitudes toward using a computer as a learning tool. Therefore, the authors paid attention to potential age difference in the evaluation of the project, to investigate how younger students and older students in engineering classrooms would perform in an e-learning environment and what impact a pre-instructional e-learning strategy would have on improving their cognitive and affective preparedness for classroom learning.

B. Analyzing Reusable Learning Objects

With reusability in mind, it was decided to select the content of e-learning modules (LOs) based on *the Introduction to Materials Science and Engineering* class (ENGR 245) taken by all engineering majors. The LOs would be reusable in higher-level courses that build upon the prerequisite knowledge gained in the introductory course. For example, a LO on the topic of atomic bonding developed for the introductory course can be reused in a 'modern physics' class and a 'bonding and crystallography' class as refresher material. A LO on a topic of vectors can be used not only in the introductory class but also in a 'statics' class, an 'engineering mechanics of materials' class, and a 'bonding and crystallography' class. With no or minimal supervision by an instructor, students in advanced classes can have an opportunity to review the prerequisite materials to prepare themselves to continue with higher-level learning. This reusability can also increase consistency in instructional contents and methods across different sections of the course and instructors. Figure 3 presents a simplified illustration of reusability analysis of seven specific LOs, and Table 1 shows a more detailed explanation.

C. Developing a Multimedia E-Learning Module

The e-learning development team consisted of a project coordinator, subject matter experts (engineering faculty), and e-learning developers (graduate assistants). Among the reusable learning objects that were analyzed (as shown in Table 1), the first e-learning module on the topic of 'Mechanical

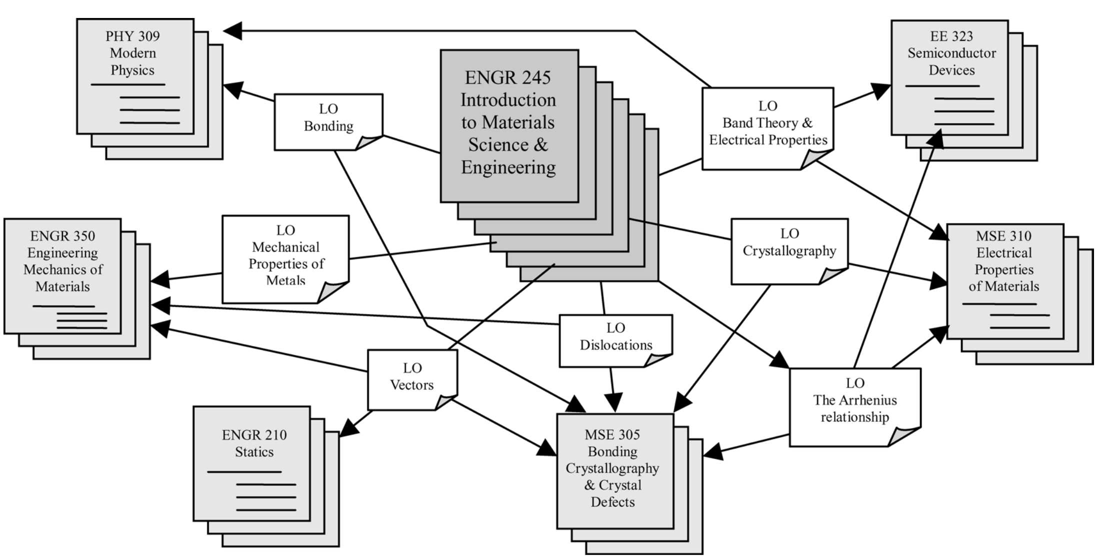

Figure 3: Developing RLOs of the Introduction to Materials Science & Engineering course.

LO Topics in ENGR 245	Other STEM courses in which the LO will be reused
The Arrhenius Relationship	– EE 323 Semiconductor Devices – MSE 305 Bonding, Crystallography, and Crystal Defects – MSE 308 Thermodynamics of Materials – MSE 310 Electrical Properties of Materials – MSE 408 Phase Transformations and Kinetics
Band Theory and Electrical Properties	– EE 323 Semiconductor Devices – MSE 310 Electrical Properties of Materials – PHYS 309 Modern Physics – PHYS 415 Solid State Physics
Atomic Bonding	– MSE 305 Bonding, Crystallography, and Crystal Defects – PHYS 309 Modern Physics
Crystallography	– EE 323 Semiconductor Devices – MSE 305 Bonding, Crystallography, and Crystal Defects – MSE 310 Electrical Properties of Materials – MSE 312 Mechanical Behavior of Materials – MSE 505 Bonding and Structure of Materials
Dislocations	– ENGR 350 Engineering Mechanics of Materials – MSE 305 Bonding, Crystallography, and Crystal Defects – MSE 312 Mechanical Behavior of Materials – MSE 505 Bonding and Structure of Materials
Mechanical Properties of Metals	– CE 352 Structures – ENGR 306 Mechanics of Materials – ENGR 350 Engineering Mechanics of Materials – MSE 312 Mechanical Behavior of Materials – MSE 512 Mechanical Properties of Materials (graduate-level course)
Vectors	– ENGR 210 Statics – ENGR 220 Dynamics – ENGR 306 Mechanics of Materials – ENGR 350 Engineering Mechanics of Materials – MSE 312 Mechanical Behavior of Materials – MSE 305 Bonding, Crystallography, and Crystal Defects
All of the LOs above	– MSE 600 Comprehensive Exam – Fundamentals for Engineering Exam for Licensure

Table 1: A list of STEM courses in which the LOs can be reused.

Properties of Metals' was developed in 2006. This e-learning module designed with multimedia (text, images, animation, video, and audio) was developed based on Gagne's nine events of instruction [9] and Cisco's guidelines for designing RLOs [32], using e-learning development software, Articulate®. As shown in Table 2, the e-learning module consisted of a module overview, instructional topics with practice, and a module test of 30 questions including multiple-choice, true-false, drag-and-drop matching, drag-and-drop sequencing, and short-answer questions. The instruction with audio narration was presented at a pre-set pace, but students could also control the sequence by using the menu on the left side of the screen. At the end of the module, a survey was presented to measure students' feelings of preparedness, confidence, and attitude toward using e-learning (see Appendix A). It was estimated that students could complete the module in an hour.

Gagne's nine events of instruction	Cisco's RLO structure	The Contents of the E-Learning Module
1. Gain attention 2. Inform learners of objective 3. Stimulate recall of prior knowledge	Introduction, relevance, objectives, prerequisites, scenario or outline	Title Module overview
4. Present new content 5. Provide learning guidance 6. Elicit performance 7. Provide feedback	A series of topics with practices: e.g., Topic 1 + practice Topic 2 + practice Topic 3 + practice etc.	Topic 1: Stress & Strain Loading types Engineering stress Engineering strain Sample calculations (practice questions) Tensile tests Topic 2: Tensile Properties Hooke's law Poisson's ratio Yielding Yield strength Elastic region Tensile strength Necking Fracture strength Ductility Toughness Design safety factor
8. Assess performance	Assessment	Module test
9. Enhance retention and transfer	Summary review	Module survey

Table 2: The design of the e-learning module.

This tutorial-type, pre-instructional e-learning module was designed mainly to facilitate knowledge and comprehension levels of learning, which can be used in different ways depending on the levels of learners. It can help novice learners prepare for the new information before their classroom learning, and it can help advanced learners to recall the prerequisite knowledge necessary for their more advanced learning. Figure 4 depicts a high-level concept model about the different uses of the e-learning module based on the levels of learners.

Figure 5 and Figure 6 are screen shots of the e-learning module and the tensile test demonstration video clip used in the module. The actual multimedia e-learning module and the video clip are also available from the web URLs.

IV. EVALUATION I: PRE-INSTRUCTIONAL E-LEARNING (FALL 2006)

A. Methods

1) Purpose: The e-learning module was implemented in the *ENGR 245 Introduction to Materials Science and Engineering* course in the fall semester of 2006 as a pre-instructional strategy, and its effectiveness for preparing students to learn during the classroom lecture was investigated. The independent variable used in the evaluation was age, and the dependent variables were the degrees of students' *cognitive* preparedness measured by the module test scores and *affective* preparedness measured by the module survey (see Appendix A) and a post-lecture survey (see Appendix B).

2) Participants: Seventy-six students were enrolled in the course, and 50 of them voluntarily participated in the study. Forty-one students (82%) were male and nine (18%) were female. Participants' ages ranged between 19 and 54. The average age was 25.78 and the median age was 24. Two age

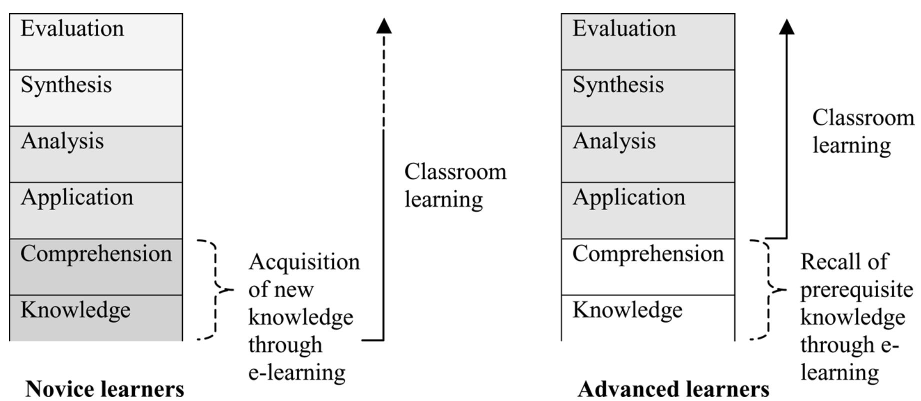

Figure 4: Different uses of the e-learning module depending on the learner levels.

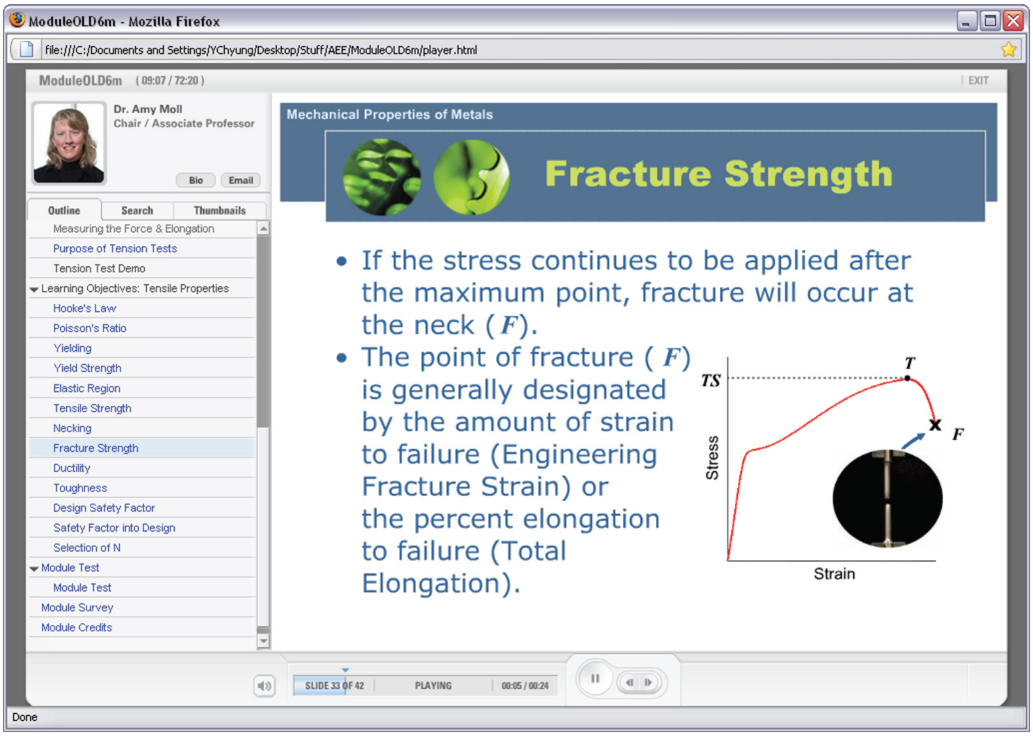

Figure 5: A screen shot of the e-learning module on 'Mechanical Properties of Metals.' (The actual e-learning module is available at http://advances.asee.org/vol02/issue01/media/13/Module/launcher.html)

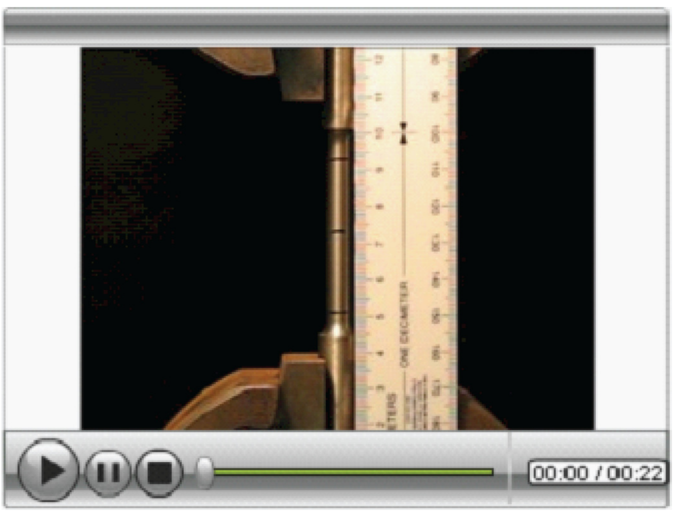

Figure 6: A screen shot of the tensile test demonstration video. (The actual video is available at http://advances.asee.org/vol02/issue01/media/13/stressstrainvideo/demo.html)

groups were formed by using the median age as the cut point—a younger group (24 years old or younger) and an older group (older than 24 years of age). Table 3 shows the demographic breakdown by age and gender.

3) Instruments and Procedure: The e-learning module was posted on a course web site, and participants were asked to complete it within three days prior to the classroom lecture that covered the topic. At the end of the module, a module test was administered to measure students' cognitive preparedness, and a module survey (Appendix A) was administered to measure their affective preparedness such as their feelings of preparedness for the lecture (Q1), confidence levels (Q2), and preference toward using e-learning (Q3 and Q4). After the classroom lecture, a post-lecture survey (Appendix B) was administered to ask students' after-thoughts about their preparedness for the lecture (Q2), confidence levels (Q3), and preference toward using e-learning (Q4 and Q5). In other words, the module survey administered at the end of the e-learning module, which students completed before the lecture, was to measure students' *predictions* of their preparedness, confidence, and attitude toward the e-learning, and the post-lecture survey was to measure their *evaluation* of the effectiveness of the e-learning module on helping them prepare for the lecture and their attitude toward using it. The overall implementation procedure is illustrated in Figure 7:

B. Results

1) Overall results: Among 50 participants, not everyone completed all four activities (1. module instruction, 2. module test, 3. module survey, and 4. post-lecture survey). Forty-two of them

	Male	Female	Total
Younger (≤24)	22	4	26
Older (>24)	19	5	24
Total	41	9	50

Table 3: Descriptive statistics on participants' age and gender.

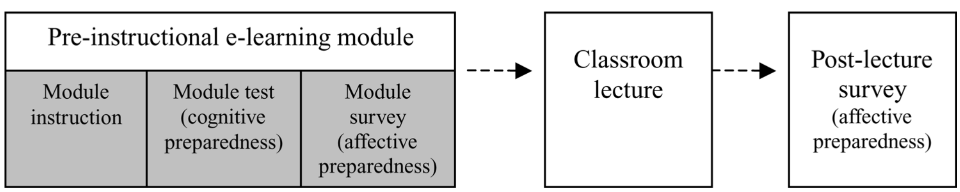

Figure 7: The implementation of e-learning and evaluation in ENGR 245.

completed the module test (i.e., eight reviewed the module instruction but skipped the module test). The scores ranged from 66.67 to 100, and the mean score was 82.78 (SD = 8.49), indicating a reasonable level of cognitive preparedness before classroom learning. Thirty-six of them submitted the module survey at the end of the module, and 42 of them submitted the post-lecture survey. Twenty-eight students submitted both the module survey and the post-lecture survey. Wilcoxon signed-ranks tests were used to check reliability between the two complete sets of nonparametric survey data [40]. The results of the module survey and the post-lecture survey, as well as the Wilcoxon test results, are summarized in Table 4.

Both surveys revealed that students thought that the e-learning module had helped them prepare for their classroom learning. Students felt very prepared for listening to the classroom lecture after having finished the e-learning module (M = 4.06, SD = .89 from the module survey, and M = 4.05, SD = .76 from the post-lecture survey). Their confidence levels indicated in the two surveys were high as well (M = 3.94, SD = .89, and M = 3.88, SD = .70, respectively). They also expressed positive reactions toward studying with the e-learning module (M = 3.31, SD = 1.14, and M = 3.48, SD = 1.10, respectively). Wilcoxon tests confirmed that the two sets of data on the first 3 items were not significantly different. However, the mean scores of the question asking if they would like to use more e-learning showed a significant increase from the module survey (N = 28, M = 3.29) to the post-lecture survey (N = 28, M = 3.68), $Z = -3.05$, $p < .01$. This result might be because after the lecture, they saw the value of the e-learning module and became more interested in using it. Students thought that the length of the program was about right or slightly longer than they would have liked (M = 3.31, SD = .58 from the module survey). The post-lecture survey included a question asking when they would prefer to use an e-learning module. Sixty-one percent of them said that they would prefer to use it *before* the lecture rather than after the lecture, 19.5% of them would prefer to use it *after* the lecture, and 19.5% of them would prefer to use it both *before* and *after* the lecture.

	Module survey (N = 36)		**Post-lecture survey (N = 42)**		**Wilcoxon test**
Question	***Mean***	***SD***	***Mean***	***SD***	**(N = 28)**
Feel prepared	4.06 (4.00)	.89 (.86)	4.05 (4.11)	.76 (.74)	$z = -.78$, $p > .01$
Feel confident	3.94 (3.93)	.89 (.72)	3.88 (3.96)	.70 (.69)	$z = -.24$, $p > .01$
Like e-learning	3.31 (3.29)	1.14 (1.15)	3.48 (3.57)	1.10 (1.14)	$z = -1.89$, $p > .01$
Like to use more e-learning	3.31 (3.29)	1.06 (1.05)	3.60 (3.68)	1.12 (1.25)	$z = -3.05$, $p < .01$

Note. The *Mean* and *SD* values shown in parentheses are for the 28 complete sets of data.

Table 4: The results of module survey, post-lecture survey, and Wilcoxon test.

2) Age difference: A t-test was used to compare the difference in module test scores of two different age groups. The difference between the two scores was significant, $t(40) = -2.22$, $p < .05$; older students ($M = 85.55$, $SD = 9.68$) performed significantly better on the module test than younger students ($M = 80.00$, $SD = 6.14$). Mann-Whitney (M-W) *U* tests were performed to compare age differences on the nonparametric data obtained from the surveys [40]. The differences in their affective preparedness (as a function of age) found in the module survey and the post-lecture survey were not significant; however, a pattern seems to exist that younger students reacted more positively to studying with the e-learning module than older students (see Table 5). This difference may reflect age differences in preference or familiarity toward online environments in general. It may also imply a potential benefit of using an e-learning strategy particularly for younger students who, based on the module test scores, seem to need more learning support to improve their academic performance to the level of older students.

V. EVALUATION II: REUSABLE E-LEARNING (SPRING 2007)

A. Methods

1) Purpose: In the spring semester of 2007, the same e-learning module was implemented as a pre-instructional strategy in *MSE 312 Mechanical Behavior of Materials*, which is a junior-level course which includes the topic of the e-learning module, 'Mechanical Properties of Metals.' *ENGR 245 Introduction to Materials Science and Engineering* is a prerequisite to MSE 312; therefore, all students who enrolled in MSE 312 are expected to have prerequisite knowledge about the topic covered in the e-learning module. However, on

	Module survey ($N = 36$)			Post–lecture survey ($N = 42$)		
	Younger	Older		Younger	Older	
Question	($N = 17$)	($N = 19$)	*M–W* test	($N = 24$)	($N = 18$)	*M–W* test
Feel prepared	$M = 4.00$	$M = 4.11$	$z = -.29$	$M = 4.17$	$M = 3.89$	$z = -1.28$
	$SD = .93$	$SD = .87$	$p > .05$	$SD = .76$	$SD = .75$	$p > .05$
Feel confident	$M = 3.88$	$M = 4.00$	$z = -.76$	$M = 4.00$	$M = 3.72$	$z = -1.19$
	$SD = .85$	$SD = .94$	$p > .05$	$SD = .59$	$SD = .82$	$p > .05$
Like e-learning	$M = 3.47$	$M = 3.16$	$z = -.69$	$M = 3.63$	$M = 3.28$	$z = -.82$
	$SD = .87$	$SD = 1.34$	$p > .05$	$SD = .92$	$SD = 1.32$	$p > .05$
Like to use more e-learning	$M = 3.47$	$M = 3.16$	$z = -.76$	$M = 3.71$	$M = 3.44$	$z = -.50$
	$SD = .80$	$SD = 1.25$	$p > .05$	$SD = .99$	$SD = 1.29$	$p > .05$

Table 5: Age differences in the results of module survey and post-lecture survey.

a pre-test administered in the first week of the MSE 312 class that covered the prerequisite knowledge of mechanical properties from ENGR 245, students scored an average of 66.82% mastery level (*SD* = 26.14), which called for a need to provide remedial instruction. Therefore, the e-learning module in MSE 312 was used to evaluate the effectiveness of *reusing* the e-learning module in this advanced course in order to stimulate students' recall of prerequisite knowledge and to prepare them for classroom learning.

2) Participants: Nineteen students enrolled in the class, but one student did not complete the course. Three students were female. Due to the small sample size, age differences in the outcomes were not investigated.

3) Instruments and Procedure: After the first use of the e-learning module in the fall of 2006, the e-learning module was modified to conform to the e-learning technical standard, Sharable Content Object Reference Model (SCORM) 1.2 [41] in order to run it on the Blackboard Learning Management System (LMS). Blackboard allows the tracking of students' learning behaviors, including the number of attempts, the completion status, time spent, and test scores. Students were asked to complete the e-learning module posted on their Blackboard course web site prior to the classroom lecture that required knowledge of the topic on *Mechanical Properties of Metals*. The overall implementation procedure is illustrated in Figure 8.

B. Results

One student started the e-learning module but left it incomplete; therefore, 17 sets of data were used for analysis. Students spent an average of 49.71 minutes on the e-learning module (*SD* = 45.22); 14 students used it once, and the remaining three students used it two, three, or five times. Everyone performed with 80% accuracy or above on the module test, and the average module test score was 92.06 (*SD* = 5.41), indicating a near-mastery level of cognitive preparedness on the specific topic before engaging in the advanced sequence of learning in the classroom.

Students' affective preparedness after completion of the e-learning module was also supported by the module survey data. Thirteen students submitted the module survey. Overall, students felt prepared (*M* = 4.15, *SD* = .80) and fairly confident (*M* = 3.62, *SD* = .96) to engage in a classroom lecture on advanced topics after having completed the e-learning module (see Figure 9 and Figure 10). However, once again,

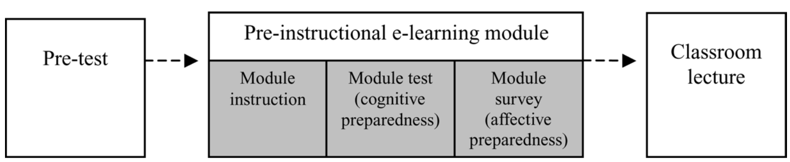

Figure 8: The implementation of e-learning and evaluation in MSE 312.

students differed in their attitudes toward the use of e-learning. While the majority of students liked the use of e-learning and wanted to use it more, three students did not like it at all (see Figure 11 and Figure 12). Also, interestingly enough, a correlation analysis revealed that their feelings of being prepared and confident

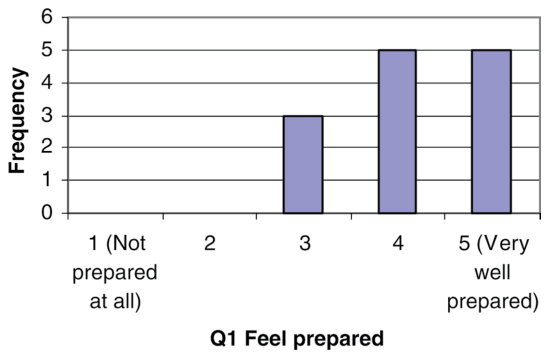

Figure 9: A bar graph of Q1 results.

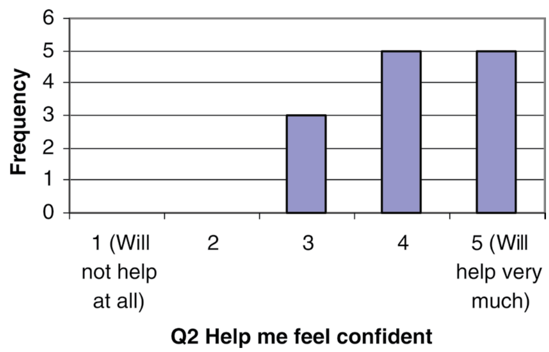

Figure 10: A bar graph of Q2 results.

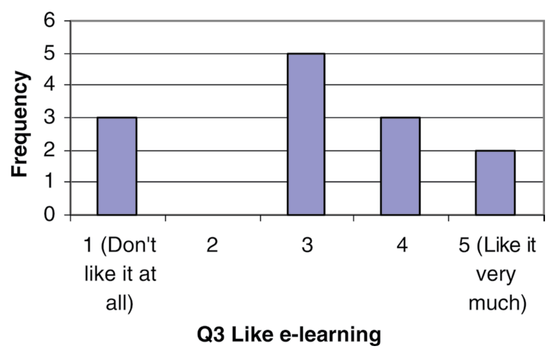

Figure 11: A bar graph of Q3 results.

were positively correlated to the degrees of their preferences in using e-learning (see Table 6). Similar to the reaction obtained from ENGR 245 students, they perceived the e-learning module to be about the right length or a little bit longer than they would have liked (M = 3.46, SD = .66).

VI. CONCLUSIONS

A. Discussions of the Findings

The main purpose of this project was to design and implement a pre-instructional e-learning strategy in an engineering curriculum to improve students' cognitive and affective preparedness for classroom learning. The pre-instructional strategy was used to *prepare* students for classroom learning, and the e-learning method was used to provide them with a self-paced learning environment. The effects of using the pre-instructional e-learning strategy were investigated in two different contexts: 1) to prepare students in an introductory class to learn new material, and 2) to prepare students in an advanced class to recall prerequisite knowledge they learned in their introductory class.

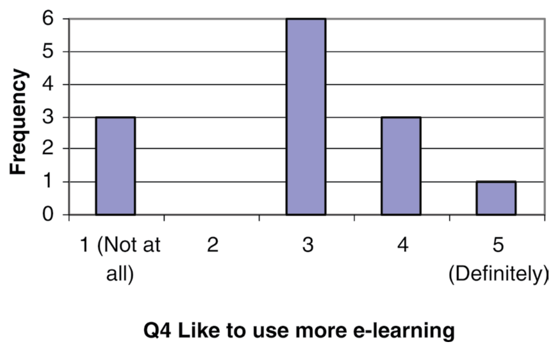

Figure 12: A bar graph of Q4 results.

Question Items	1	2	3	4
1. Feel prepared	–	–	–	–
2. Feel confident	.77**	–	–	–
3. Like e-learning	.60*	.79**	–	–
4. Like to use more e-learning	.57*	.80**	.88**	–

Table 6: Correlations among the data obtained from the module survey.

The overall effectiveness of using the pre-instructional e-learning strategy before learning new material is well summarized by the following student comment obtained from the module survey, "Overall, pretty effective in giving a heads-up about the lecture material." However, results from the first evaluation study indicated that the effectiveness of, and attitudes toward, using a pre-instructional e-learning strategy might differ depending on students' age. After completing the e-learning module, older students were cognitively better prepared for classroom learning than younger students were, but younger students seemed to like the use of e-learning slightly (but not significantly) more than older students did. Such knowledge about learners' characteristics enables instructors to tailor their instruction and to utilize more effective instructional strategies for different learners. It is particularly important to do so during the early years of engineering programs when the overall student success rates and retention rates are low.

The use of the pre-instructional e-learning strategy in the advanced course was proven to be effective as well. Although students' preferences in using e-learning differed, the second evaluation study revealed that students' recall of prerequisite knowledge was close to the mastery level after they had completed the e-learning module. This result reinforces the premise of the project for implementing a RLO-based pre-instructional e-learning strategy in curriculum development to improve its cost effectiveness. In retrospect, had the pre-instructional e-learning strategy not been implemented before the lecture in the advanced class, the instructor would have had to spend time in her classroom, reteaching students to help them recall prerequisite knowledge. Or, students with low levels of readiness might have had difficulty following the information presented in the advanced class.

B. Limitations of the Project

This project has several limitations. First, the use of convenience samples limits generality of the evaluation findings only to Boise State University (i.e., a small population), and due to the small sample sizes, any significant or non-significant results of the inferential statistics obtained from the evaluation studies should be interpreted with caution. Second, the first evaluation study revealed age difference in the module test scores; however, the result could have been influenced by other confounding factors such as other learner characteristics including gender, students' GPA, access to computers, and the number of credits enrolled, to name a few. For example, gender is another learner characteristic that deserves attention. However, only nine female students participated in the first study, which was not a sufficient number of subjects for evaluating gender differences with inferential statistics. Third, it was not feasible to use a control group in the evaluation studies to make a between-group comparison in addition to the within-group comparison. Whether the improved cognitive and affective preparedness outcomes reported in the evaluations were indeed due to the pre-instructional e-learning strategy or influenced by other factors would not be certain without comparing the results to the control group's outcomes. With this project being exploratory, focusing on the development and implementation of the project, a more rigorous experimental research was not designed into the evaluations. Fourth, the project team also experienced a learning curve during the project in terms of the technical aspects of designing and developing the e-learning module. For example, in retrospect, more practice examples should have been included in the e-learning module (Gagne's events #6 Elicit Performance and #7 Provide Feedback), and more cognitive feedback could have been employed in the module test. Different designs of the e-learning module could produce different results.

C. Lessons Learned

From this project, the authors not only learned about the overall effectiveness of incorporating a pre-instructional e-learning strategy in an engineering curriculum on improving students' cognitive and affective preparedness for classroom learning, but also increased their understanding of useful e-learning design strategies and fundamental principles of instructional design for future projects. Here is a summary of the lessons-learned.

1) Fully incorporate an e-learning strategy in the course: Despite the general consensus, as discussed in this paper, that the pre-instructional e-learning strategy helped students feel better prepared and improve confidence levels, anecdotal data indicated that some students felt that the instructors were adding more work to the existing course workload and that they did not view it favorably. Therefore, it would be better to incorporate the e-learning strategy into the coursework from the beginning of the course, by using them as *scheduled* assignments, while monitoring the overall course workload and maintaining the quality and quantity of subject material being covered.

2) Do not replace the good ol' book-reading assignment and personal coaching with e-learning: E-learning is not a panacea. It is a *strategy*, and different learners use, or prefer using, different strategies to maximize their learning. Therefore, a pre-instructional e-learning strategy should not be used to replace other options such as reading a textbook or asking questions to the instructor or peers. The personal preferences are evidenced by the following comments that some of the participants of the studies made to the open-ended question in the module survey:

"I prefer the classroom and the interaction with a real person."
"Pretty cool, but nothing really beats a good book over the material."
"I would much rather read the book before class, but that may just be me."

With that in mind, e-learning that is redundant to reading a textbook should be avoided. Instead, e-learning should be designed with unique instructional methods, such as providing more interactive learning stimuli, more application and analysis types of practice questions, and immediate feedback. E-learning has these capabilities, as explained in the following items.

3) Design e-learning to maximize the benefits of self-paced learning and multimedia capabilities: Learner preferences also differ in the use of multimedia and the degree of learner control during the participation in e-learning. Several students' comments in the module survey show their preferences in using multimedia elements and having control over the learning sequence:

"I liked the visual aids. They were helpful in visualizing the content."
"I liked it when arrow pointed to what was being talked about."
"I like this. It helped because I could read this as many times as I needed and study at my own pace."
"I would include a button to either skip quiz questions, or go back and review previous quiz questions."

E-learning has such capabilities, and e-learning designers should incorporate them into their products to maximize the benefits of self-paced learning and to support learner preferences.

4) Improve 'transfer-of-learning' with 'real-world' examples: The e-learning module used in this project was designed to facilitate the acquisition or recall of knowledge and comprehension levels of learning (knowing what). However, e-learning modules can be designed for different types and levels of learning. Since many students leave engineering programs due to a misunderstanding between the relevance of their early coursework and a future engineering career, e-learning modules could be implemented in a manner to aid in making the link between the early, general courses and a future engineering career. One method for forming such a link is to incorporate "real-world" applications into the e-learning design. To solve these "real-world" examples, students would have to utilize the concepts and principles being covered by a particular module. In other words, e-learning could be designed to provide not only declarative knowledge (knowing what), but also procedural knowledge (knowing how) and situated knowledge (knowing when/why) [42]. Different instructional methods should be used for different types of learning contents, and the degree of "real-world" applications would increase as the amount of 'procedural' and 'situated' knowledge increases (see Table 7). By instituting "real-world" examples in e-learning, a direct link could be made between the coursework and the problems being addressed by practicing engineers. In addition, these examples could improve students' understanding of engineering careers and instill in them an underlying reinforcement of life-long learning goals.

5) Increase the degree of reusability of LOs through a spiral curriculum: RLO-based e-learning products are better designed and implemented within a *spiral curriculum*, which is a curriculum development method that Jerome Bruner, an educational psychologist at Harvard University,

Learning Contents	Declarative knowledge (Knowing what)	Procedural knowledge (Knowing how)	Situated knowledge (Knowing when/why)
Instructional Methods	Drill and practice	Show and tell (demonstration)	Scenario/problem-based (simulation)
Degree of "real-world" applications	Low	Medium	High

Table 7: Types of learning contents and instructional methods.

proposed about a half century ago. Improving 'readiness' is the key in a spiral curriculum, as Bruner [43] explains in the following:

> Readiness … consists of mastery of those simpler skills that permit one to reach higher skills. Readiness for Euclidian geometry can be gained by teaching intuitive geometry or by giving children an opportunity to build increasingly elaborate constructions with polygons. Or, to take the aim of the new, "second-generation" mathematics project, if you wish to teach the calculus in the eighth grade, then begin it in the first grade by teaching the kinds of ideas and skills necessary for its mastery later. (p. 29)

A spiral curriculum would not only support the design and implementation of RLOs to be used in multiple courses but also facilitate the improvement of students' cognitive and affective preparedness. It requires collaboration among the instructors of a series of courses to analyze reusability of contents and to design and develop RLOs. In their classrooms, students should be repeatedly informed that specific topics will be used as prerequisites in upper-level coursework, and they could use a variety of RLOs to improve learning. Doing so would also help students recognize "the cumulative power of learning" [43, p. 30], which in turn reinforces their continuous motivation to learn and their understanding of the connection between the early subject matter and a future engineering career.

6) The shorter the RLOs, the better: Because the goal is not just to develop *reusable* materials, but also to ensure that they will be effectively *reused*, it is important to consider how to motivate students to use the RLOs in both formal and informal learning contexts. In addition to including multimedia components and real-world examples as motivational strategies, the development team has agreed that the shorter the RLOs are, the more useful they become. A desirable length of each RLO is 30 minutes or less. That way, students can select and review the ones that they need in a short time, which will help sustain their motivation to use them again, as needed.

D. The Follow-Up

Since the initial development and evaluations reported in this paper, ten additional e-learning modules have been developed on the topics of mechanical properties, crystal defects, phase diagrams, eutectic phase diagrams, the iron-carbon phase diagram, dislocations and slip systems, and energy band diagrams. All e-learning products are SCORM-conformant, so that students' learning processes are tracked through a SCORM-conformant learning management system, Blackboard. The e-learning modules have been implemented in ENGR 245 class (60–70 students each semester) and MSE 312 class (17 students each year) as a pre-instructional strategy. The modules are also made freely available via the college website for any students who wish to use them to prepare for their Fundamentals for Engineering Exam for Licensure.

ACKNOWLEDGEMENTS

This work was supported in part by the National Science Foundation under Grant No. 0530139. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors appreciate co-principal investigators of the grant, Dr. Knowlton and Dr. Müllner, for their contributions to this project.

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APPENDIX A. MODULE SURVEY

Q1. After completing this self-paced program, how prepared do you feel to listen to the classroom lecture on this module?

Not prepared at all 1 2 3 4 5 Very well prepared

Q2. Will this self-paced program help you to increase your confidence in understanding the classroom lecture?

Will not help at all 1 2 3 4 5 Will help very much

Q3. How much do you like studying with self-paced programs like this?

Don't like it at all 1 2 3 4 5 Like it very much

Q4. Would you like to have more self-paced programs like this?

Not at all 1 2 3 4 5 Definitely

Q5. How was the length of the self-paced program?

Too short 1 2 3 4 5 Too long

Q6. Please write any suggestions regarding this e-learning module:

APPENDIX B. POST-LECTURE SURVEY

Q1. Did you complete the self-paced program before you came to the classroom lecture on this module?

____ Yes ____ No (If your answer is no, stop here and submit your survey)

Q2. Because you completed the self-paced program, how prepared did you feel to listen to the classroom lecture on this module?

Not prepared at all 1 2 3 4 5 Very well prepared

Q3. Did the self-paced program help you to increase your confidence in understanding the classroom lecture?

Did not help at all 1 2 3 4 5 Helped very much

Q4. How much do you like studying with self-paced programs like the one that you completed?

Don't like it at all 1 2 3 4 5 Like it very much

Q5. Would you like to receive more self-paced programs that support classroom lecture?

Not at all 1 2 3 4 5 Definitely

Q6. When would you like to use a self-paced program?

____ I would rather use it before I come to the classroom lecture.

____ I would rather use it after I attend the classroom lecture.

____ I would like to use it both before and after the classroom lecture.

Q7. Please write any suggestions regarding the use of self-paced programs: