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Development of a Framework for the Online Portaion of a Hybrid Engineering Course

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Development of a Framework for the Online Portion of a Hybrid Engineering Course

Abstract

The paper describes the development of a research-based framework that can be used to design the online component of a hybrid engineering course. This framework was tested in an undergraduate course entitled Construction Equipment and Heavy Construction Methods. The multimedia design decisions are grounded on evidence-based findings from cognitive theories and experimental evaluation studies. Instructional design decisions are matched with course objectives and supportive findings from the literature review. The online component is designed as a series of interactive modules that teach students how to solve engineering problems with definitive answers. Each module is a stand-alone unit that can be used as preparation for the onsite portion of the class, after the student has completed reading the related chapter in the text book. The modules are used to prepare students for solving open-ended questions in a face to face part of the course. Also, the module can serve as a study guide for review purposes. In the modules, students view the video demonstrations of how to solve problems and then practice problem solving step by step with verification (correct/incorrect) and explanatory program feedback presented for each step.

The pilot development of the modules with six participants was conducted, and a plan for the refinement of the modules design was laid out. The educational design research methodology was used, which not only targets the problem of designing an online component for this specific course, but at the same time seeks new knowledge that can inform the work of others facing similar problems. The lessons learned from this experience and the future directions that the authors intend to take are presented in this paper.

Keywords: educational design research, teaching hybrid courses in civil and construction engineering, web-based interactive multimedia design and evaluation

Introduction

The research methodology entitled *educational design research* is a combination of scientific investigation with systemic development and implementation of solutions to educational problems. "In the field of education, design research is distinguished from other forms of scientific inquiry by educators of its commitment to developing theoretical insights and practical solutions simultaneously in real world (as opposed to laboratory) contexts." (McKenney & Reeves, 2012, p.7). As stated by Bereiter (2002) "Design research is not defined by its methods but by the goals of those who pursue it. Design research is constituted within communities of practice that have certain characteristics of innovativeness, responsiveness to evidence, connectivity to basic science, and dedication to continual improvement." (p.321).

Unlike evaluation research that is "primarily concerned with evaluating and possibly improving the qualities of a particular intervention", design research has a "broader scientific orientation of generating usable knowledge." Educational design research involves testing and refinement of both the prototype solutions and the design principles upon which they are based (Reeves, McKenney, & Herrington, 2011). This research uses the methodology of educational design research and describes developing and testing a "generalizable" framework for the development of an online component for a hybrid engineering course.

Hybrid learning course model consists of classroom face-to-face interaction and online computer – mediated communication (Mitchell & Honore, 2007). The terms "hybrid instruction," "blended instruction," "technology-mediated instruction," and "mixed-mode instruction" are often used interchangeably in current research literature. Typically hybrid courses include e-learning activities such as online lectures, online quizzes, synchronous or asynchronous discussions, and group work sessions (Vernadakis et al., 2011). The previous research indicates that students in hybrid courses were equally successful or even more successful compared to students in traditional courses (Young, 2002; Means et al., 2010). "The hybrid online model employs the best characteristics of online education and the interactivity that typically characterizes face to-face classroom instruction" (Martyn, 2003, p.1).

Even though the hybrid model has been successfully adopted by many universities in a variety of courses, its implementation in teaching engineering courses has been both enjoying achievements and facing challenges. The hybrid model that was employed at UW-Madison across the College of Engineering included both online lectures and face-to-face group work sessions. Along with the positive student feedback about the ability to pause the online videos and write down notes, concerns about homework submissions and student inability to absorb the information were raised. "I feel like a massive amount of content is being thrown at me in a short amount of time, and often this feels overwhelming and I don't absorb it all. And when I am confused [during an online lecture] I can't ask a question until Wednesday morning and I usually have forgotten what or why I was confused" (Sheppard, n.d.).

After working with edX, the joint experiment with free online courses that MIT and Harvard started, Mr Agarwal , the first president of edX, outlined the future directions for the use of the hybrid model in teaching engineering courses: "Future MIT students will experience a blended education with videos and auto-graded exercises online, and in-person time spent on labs, research and group problem solving. " (Parry, 2012).

In our investigation, we designed, developed and pilot tested an online interactive scaffolded modules that combine video demonstrations and auto-graded exercises online. Instructional scaffolding is the support given to the learner during the learning process. "Scaffolding is a way of providing feedback for parts of a learning process. As the learner becomes more skilled, the scaffold can be removed and the learner provides for himself or herself what the scaffold had provided." (Brooks & Crippen, n.d.).

In the designed modules, scaffolding is initially provided through worked out examples and later through immediate explanatory program feedback that is presented to students on each step of their problem solving practice. Worked examples provide a sequential process of learning. "Worked examples are a step-by-step demonstration of how to perform a task or solve a problem." (Clark, Nguyen, Sweller, 2006, p.190). Worked examples can be presented in different formats: animated demonstrations, textual descriptions, or video-taped expert demonstrations. In our modules, we use video-taped expert demonstrations. Worked out examples are proven to be the most effective way of learning during the initial stage of learning. All other things being equal, measured learning outcomes from scaffolded worked examples give better outcomes than do open-ended inquiry projects without scaffolding (Taconis et al., 2001).

The Overall Goal of this Research

The development of a framework for designing an online component of an engineering hybrid course was the overall goal of our research. The prototype of the framework was designed and tested in a Construction Equipment and Heavy Construction Methods undergraduate course. The online part of the hybrid course was a series of interactive modules that demonstrate problem solutions (see Fig. 1) and allow students to practice solving similar problems in a step by step interactive scaffolded learning environment (see Fig. 2, 3). The problem demonstrations are chunked with a series of questions gauging student comprehension of the key points (see Fig.4). Student performance in the step by step learning environment is augmented with explanatory feedback (see Fig.3). Figures 1-5 can be found in Appendix A. Each module is a stand-alone unit that can be used as preparation onsite sessions after the student has completed related reading of the text book. The multimedia design decisions are grounded in the evidence-based findings from cognitive theories and experimental evaluation studies. Instructional design decisions are matched with course objectives and supportive findings from the literature review (see Table 1).

The modules serve as a tool to prepare students for independent problem solving (solving problems with definitive answers without breaking the problems up into steps) in class and online (see Fig. 4) and solving open-ended questions in a face to face part of the course. The use of online modules was expected to replace classroom time where example problems are solved by the instructor. The classroom time saved by using the modules was re-allocated to time for students to solve ill-defined problems (open-ended questions) in a small group discussion format.

This paper documents the process of using the educational design research methodology for the design, development and testing of the modules. In this research, various steps in the process including usability testing and user interface analysis of the module prototypes are described. Summarized herein is a pilot testing effort that included a series of small-scale formative evaluations of the module prototypes that continued until satisfactory outcomes had been reached by all concerned: students, instructors, and designers. The prototype testing took place in a real instructional setting.

An important task that was undertaken during the study was to obtain indications of the quality of the modules and collect formative data that could improve their design. Student perceptions were collected and analyzed on several dimensions using Learning Object Review Instrument (LORI) (Leacock & Nesbit, 2007). Recommendations that were considered in improving the design of the modules were based on students' perceptions of the value of the modules, instructor's comments obtained through interviews, and the data from the electronic course management system (Blackboard Learn) about how students used the modules.

Literature Review

Learning effectiveness depends highly on interaction (Garrison & Anderson, 2003; Hannafin, Hill, & Land, 1997). Interaction engages students in deep and meaningful learning. It can be interaction with the instructor, with other students, and with the content (Moore & Kearsley, 2005). Students think that using interactive technologies improves their understanding of the course material (Moore & Kearsley, 2005).

In contrast to previously developed hybrid courses, in our hybrid course design framework, we included interaction in the online component, and the online modules were designed to support deep student-to-content interaction. The modules included video demonstrations of example problem solutions and provided the environment for step-by-step problem-solving with immediate explanatory program feedback. In the modules according to the revised Bloom's taxonomy (Anderson & Krathwohl, 2001), student interaction with the content took place on the following three dimensions: remember, understand, and apply (see Fig. 6). The modules were designed to help students build procedural knowledge as a foundation for solving authentic engineering problems.

The higher level of interaction with the material was expected to happen during the face-to-face part of the course, where students worked in groups to solve engineering open–ended questions (ill-defined problems). They had to analyze the problem space, create the solution, and evaluate it. Thus, through the entire course (online and face to face), students interacted with the content on the six cognitive dimensions according to Bloom's revised taxonomy: remember, understand, apply, analyze, evaluate, create (see Fig. 6).

Another aspect of our investigation was to design a framework that took advantage of the opportunities for effectiveness and efficiency of a hybrid engineering course. As stated by Spector (2005), there are some studies that have addressed the issue of learning effectiveness of online courses (Steeples & Jones, 2002) , but there are very few studies that explored "the implications of a particular technology with regard to the ability of teachers and learners to perform effectively and efficiently in a particular instructional setting (Spector, 2005). Also, design of online multimedia learning materials is frequently not informed by relevant research in psychology and education (Nesbit, Li, & Leacock, 2006; Shavinina & Loarer, 1999). Also, according to Nam & Smith-Jackson (2007), even though web-based courses and programs have increasingly been developed by many institutions, many developmental approaches do not integrate the user interface design with instructional design.

To address this issue, we anchored multimedia instructional design decisions and program features that were implemented in the modules to cognitive theories and the findings from experimental studies. Moreover, one of the major findings from the literature review was that it is a challenge to find the optimal mix of online and face-to-face instruction that will leverage the major advantage of asynchronous learning (any time, any place), while still maintaining a reasonable level of quality for faculty-student interaction (Martyn, 2003, p.2).

Thus, we focused our literature review on two dimensions: the software features that can potentially support the efforts of students to build procedural knowledge as a pre-requisite for solving authentic ill-defined problems (open-ended questions) and crucial factors for successful inclusion of online computer assisted learning to support eventual face to face learning. Based on our analysis, worked examples, segmenting, feedback, and learner control were identified as crucial elements for successful algorithmic problem solving (solving problems with definitive answers) in a computer-assisted learning environment. The findings for each dimension are presented below.

Worked examples.

"A worked example is a step-by-step demonstration of how to perform a task or how to solve a problem" (Clark, Nguyen, Sweller, 2006, p. 190). As stated by Van Merrienboer (1997), studying worked examples is an effective instructional strategy to teach complex problem-solving skills.

Sweller and Cooper used worked examples as a substitute for conventional problem-solving for those learning algebra. The results revealed that students who studied worked examples, performed significantly better than learners who actively solved problems (Sweller & Cooper, 1985; Cooper & Sweller, 1987). According to Kalyuga, Chandler, Tuovinene, and Sweller (2001), "A series of worked examples should be presented first. After learners become more familiar with the domain, problem solving (as well as exploratory learning environments) can be used to further enhance and extend acquired skills" (p.588).

Segmenting the material.

Based on the findings from cognitive psychology, segmenting information by steps into small chunks of information is crucial because it helps the learner understand and retain the information presented in the training. "Students understand a multimedia explanation better when it is presented in learner-controlled segments rather than as a continuous presentation. " (Mayer & Moreno, 2003, p.47).

Program feedback.

In educational contexts, feedback is considered crucial to improving knowledge and skill acquisition (Azevedo & Bernard, 1995; Epstein et al., 2002; Moreno, 2004; Pridemore & Klein, 1995). Research has shown that formative feedback reduces uncertainty between students' performance and goals and enhances learning (Ashford , Blatt, & VandeWalle, 2003; Bangert-Drowns, Kulik, Kulik, & Morgan, 1991). Design timing of feedback needs to be aligned with the desired outcome. The use of immediate feedback is appropriate for difficult tasks (Clariana, 1990; Shute, 2008). Low achieving students need the support of immediate feedback in learning new tasks (Mason & Bruning 2001). Phye and Sanders (1994) found that for conceptual and procedural learning tasks feedback needs to be specific and clear.

Learner control.

Learner control allows the learner a range of choices in learning tools (for example, the learner can decide what tools he/she wants to use in a software), an ability to adjust the pace of system-paced instruction (for example, the learner can choose the pace of pre-recorded videos of problem solution demonstration), and the range of navigation paths (for example, the learner can choose to skip some parts of the software). The findings on leaner control of the level of instruction suggest that many learners are unable to accurately self-monitor their progress towards learning goals (Zimmerman, 1998) or their need for assistance (Aleven, Stahl, Schworm, Fischer, & Wallace, 2003). Learners make better decisions about their learning when they are advised to use relevant information (Williams, 1996; Eom & Reiser, 2000). For this reason, Clark, Nguyen, Sweller (2006) recommend avoiding exploratory architecture for novice learners. On the other hand, they suggest that learners need to be provided with the opportunity to adjust instruction to their own pace (Clark, Nguyen, Sweller, 2006).

Description of the Online Modules

The modules are learner directed online tools to be used by students without direct instructor supervision. The modules were designed by using the Lectora Inspire, e-learning authorizing software (2013), and published to SCORM. The SCORM publishing provided by Lectora Inspire allows seamless integration of the modules into the Blackboard Learning Management System (LMS). The scores of students' performance through the modules are recorded in the Grade Center of the Blackboard Learning Management system used by the university. Furthermore, in addition to PC and Mac platforms, Lectora offers seamless e-Learning to HTML5 publishing on mobile and tablet devices such as iPad, iPhone, Android phones etc.

Even though the above technical parameters such as seamless Blackboard LMS integration and HTML5 publishing were considered when choosing e-learning software and authorizing tool, the major focus of our research effort was to determine the educational value of the modules. The modules consisted of video demonstrations of how to solve multiple step problems with definitive answers (see Fig. 1), step by step practice with immediate explanatory feedback (see Fig. 2 & 3) and independent problem solving practice (See Fig. 4). The video demonstrations were chunked into segments followed by comprehension questions (Fig. 5). Each module was designed to help students gain some declarative (factual and conceptual), procedural (how to solve well-defined problems) and conditional (when to use what) knowledge. The Figures 1-5 can be found in Appendix A.

Explicit instruction was chosen as an instructional strategy for teaching students how to solve well-defined problems. “Explicit instruction is characterized by a series of supports or scaffolds, whereby students are guided through the learning process with … clear explanations and demonstrations of the instructional target, and supported practice with feedback until independent mastery has been achieved” (Archer & Hughes, 2011, p.1). The instructional design decisions identified in the literature as potentially effective were matched with supportive research findings and presented in Table 1.

Table 1 Instructional design decisions used in the modules and supportive research findings

Instructional Design Decisions	Learning Activities	Supportive Research Findings
1. The use of worked out examples	The videos demonstrating how to solve well defined problems were recorded using Camtasia Studio software. Zoom-n-Pan, Callouts, Cursor effects were used for cueing purposes. The videos included the decision-making process for problem solution.	1. Studying worked examples is an effective instructional strategy to teach complex problem-solving skills (van Merriënboer, 1997) 2. Format worked examples in ways that manage cognitive load in multimedia through audio narration of steps and cueing of related visuals (Clark, Nguyen, Sweller, 2006).
2.The use of step by step problem solving strategy followed by problem solving without scaffolding (independent practice)	The software allowed students to solve well-defined multiple step problems one step at a time for mastering the algorithm of problem solution. After that, students were presented with a well-defined problem without step by step segmenting.	Novices need support from the instructional environments to substitute for their lack of prior knowledge of the material (Clark, Nguyen, Sweller, 2006). 2. "Segmenting complex skills into smaller instructional units of new material addresses concerns about cognitive overloading, processing demands, and the capacity of students' working memory. Once mastered, units are synthesized (i.e., practiced as a whole)." (Archer & Hughes, 2011, p.2).
3. Segmenting the material	The video demonstrations of step by step problem solutions were broken into segments for imposing the material gradually. The comprehension questions were included between the video segments for helping students check their understanding of the material.	1. Reducing the amount of content presented in one time is important for managing students' cognitive loads (Clark, Nguyen, & Sweller, 2006).

Instructional Design Decisions	Learning Activities	Supportive Research Findings
4. Checking student comprehension of the material between segments	Students were presented with questions and explanatory feedback on each step of their learning.	1.“…eliciting increased numbers of student responses enhances student engagement.” (Archer & Hughes, 2011, p. 2)
5. Learner-pacing	Students were provided with the tools to self-pace their learning at any time through the whole module.	1.“...the decisions on how rapidly an instructional sequence should proceed can best be made by the learner.” (Clark, Nguyen, & Sweller, 2006, p.181).
6. The possibility for students to choose between worked examples and step by step practice	The software navigation allows students to skip worked examples and go directly to step by step problem solving.	1.“ With more experience in the domain, worked examples became redundant and problem solving proved superior. It is suggested that the relative effectiveness of either worked examples or problem solving depends heavily on levels of learner knowledge” (Kalyuga, Chandler, Tuovinen, & Sweller, 2001, p.579).
7. Use of immediate explanatory feedback	1. Students were presented with the correct/ incorrect and explanatory feedback on each step during problem solving .This allowed students to clarify their possible misunderstandings early in the process. 2. Students were presented with correct/incorrect explanatory feedback on their answers to comprehension questions between the segments of the worked example videos.	1. Formative feedback reduces uncertainty between students’ performance and goals and enhances learning (Ashford et al. 2003; Bangert-Drowns et al. 1991). 2. The use of immediate feedback is appropriate for difficult tasks and novice learners who do not have prior experience with the information taught (Clariana, 1990; Shute, 2008). 3**.**“Provide immediate affirmative and corrective feedback. Follow up on students’ responses as quickly as you can. Immediate feedback to students about the accuracy of their responses helps ensure high rates of success and reduces the likelihood of practicing errors.” (Archer & Hughes, 2011, p. 3).

Evaluation Methods and Procedures Grounded in the Literature Review Findings

According to Cronbach (1982), formative evaluation consisting of multiple small studies can be instrumental if its purpose is to understand how the program works and how to improve it. Therefore, we decided on the format that combines the benefits of usability testing (how easy the modules are to use) and user-interface analysis (what students think about how the program helps them learn). During the developmental stage, we conducted a pilot study of the modules during the 2012 Fall Semester. The collected information was used for the refinement of the module design.

Traditionally, highly detailed evaluation approaches are labor and time-intensive (Jones et A., 1999). In our design study, the heuristic approach to evaluation using the Learning Object Review Instrument (LORI) was combined with usability testing. The heuristic approach was used for user-interface analysis. The LORI was chosen because it strikes a pragmatic balance between depth of assessment and time (Leacock & Nesbit, 2007). "The LORI enables learning object users to create reviews consisting of ratings and comments on nine dimensions of quality: content quality, learning goal alignment, feedback and adaptation, motivation, presentation design, interaction usability, accessibility, reusability, and standards compliance" (Leacock & Nesbit, 2007, p.44) The standard compliance dimension was excluded as not applicable for the evaluation of this module.

The usability testing approach was used for immediate elimination of basic navigation problems at the early stage. Usability testing differs from most other kinds of feedback-gathering methods because it is based on direct observations of people using the product. As stated by Jeffries, Miller, Wharton, & Uyeda (1991), when comparing four formative evaluation techniques "Usability testing did a good job of finding serious problems…and was very good at finding recurring and general problems, and at avoiding low-priority problems."

For triangulation purposes, the data were collected from three perspectives: students'(paper-based survey, individual interviews, informal observations of program use during which students were engaged in learning focused dialogues), instructors' (interview with the instructor about how well the hybrid component met the learning objectives, student learning needs, and student learning outcomes at the 3 tests during the course), and multimedia instructional designer's (data about actual use of the program coming from data base in Blackboard Learning Management System.

Subjects.

The sample consisting of six participants is described below.

1. Four participants were enrolled in the fall 2012 course, and the other two completed the course two semesters ago when the modules were not used in the course.
2. Among the four students enrolled in this course, there were two high achieving and two low achieving students.

3. Two participants did not have high speed internet connection at home.
4. One participant was a teaching assistant for a different course. Another participant has been working full time.

Data collection and analysis plan.

During the fall semester of 2012, a web-enhanced construction equipment course was offered at ISU. The course offering is a three credit course that had been scheduled to meet 2 times per week with a lecture meeting on one day and a lab another day. The modules were used as online home preparation for the lab. The use of modules was not required during the course. The scores of students' correct/incorrect answers through the modules were not included in the calculations of student final grade, and students did not receive any bonus points for the use of the modules. The data about how students used the modules and the educational value of the modules came from four sources:

1. A user-interface analysis was conducted with the six students. Data about students' attitudes with regard to various components of the modules were collected during the semi-structured debriefing session with individual students. Student input was important to collect information for possible modifications and gauge in what parts of the modules students are investing their time and why some parts of the modules were more preferable than others. Also the data from the students helped the researchers to tentatively evaluate the effectiveness of the modules (whether the modules help students learn or not) and efficiency (whether the time spent on the modules was comparable to their educational value).
2. Usability testing with the six students for evaluating the ease of navigation. Informal observations of how students used the modules were conducted followed by a semi-structured debriefing session. The participants were engaged in learning focused dialogues about effectiveness of program features and instructional design decisions implemented in the modules.
3. Instructor and teaching assistants' observations regarding the level of student success in the course and the use of the modules.
4. Data from the Blackboard Learning management system. There is a feature that tracks student access to course management activities, such as accessing the online module files. The frequency of students' accessing of the files was tracked and analyzed. We were particularly interested whether the use of modules is more or less favored but "A", "B" or "C" students.

Results

The results presented in this paper are categorized by the above information sources.

User-interface analysis and usability testing.

In tune with the Learning Object Review Instrument (LORI), the six participants created reviews on eight broadly interpreted dimensions of quality. The themes on each dimension and students' supportive comments were tabulated below by each dimension. The dimensions were rated by the participants on the rating scale of five (1- not helpful at all; 2-not helpful; 3-somewhat helpful; 4-helpful; 5-very helpful). All the users emphasized the content quality (see Table 2).

Table 2 Students' reflections on the content quality of the modules

Themes	Average Ratings	Supportive Comments
The modules have high educational value	4.8	1). I notice that they (the modules) do teach us.
		2). Step by step instruction, interactive, user-friendly, keeps you engaged.
		3). The videos are really boring, but the info is good. With my attention problems, the interaction helps. If it were a module for an online course, I would give it a rating of 5 out of 5.
		4). Compared to other classes taken online it is much better than what is available now.
		5). I understood the material fairly well (the student spontaneous comment after going through Module 11).
		6). The concept of the Module design is solid.

The students made positive comments on the alignment of what they learn through the modules with the in-class lab activities and the exams (see Table 3). As to alignment with learner characteristics, even though all the participants admitted the high educational value of the modules, various parts in the modules were redundant to several students. This raises a concern of giving students a tool to better navigate through the modules so that some steps can be easily skipped without the possibility of skipping key elements.

Table 3 Students' reflections on learning goal alignment

Themes	Average Ratings	Representative Supportive Comments
1. The modules help students' preparing for in-class exams	4.5	I would use the modules for preparing for the exams, if I do not understand some parts; I like that I can pick and choose with the modules.
2. The modules align with learning activities in the in-class labs	5	1Step by step instruction really helps you get started with assignments in class.
3. The modules align with learner characteristics	3	1). The information in the video demonstrations is sometimes redundant.

Motivation.

According to expectancy-value theory (Wigfield & Eccles, 2000) motivation is a function of the value placed on a task, one's expectations about the task, and the perceived cost of the task. The participants found the modules an important learning tool that allowed them online one on one practice with feedback at their convenience (see Table 4). But, at the same time, students found the modules extremely time consuming if used as extra work on top of their work in the lab class. This had a negative effect on students' motivation to use the modules to full extent.

Table 4 Students' reflections on the motivational value of the modules

Themes	Average Ratings	Supportive Comments
1.Value placed on task: students think that one on one learning at their own pace is beneficial to them	5	But I like this (the modules) to be able to do problems on my own. And in class sometimes you work with the partner, and the partner just wants to get done and out and may not explain it to you the part that he has done. You know, it happens a lot in many classes; one person will take over and just do the work. And it is good for this person. He is going to get a good grade. But the other two or three students in the group are out of luck. So it is kind of nice to learn it at your own pace with this module. Sometimes in class you rush through just to get the problems done. And it is not as beneficial, I think.
2. Expectations about the task: Students expect less time spent on a hybrid course	2	It is almost like I know it will help us but it is not necessary at the moment. But if we can choose not go to class it would be necessary and more feasible. Because this is not feasible: two hours of class and two hours of training through the module. And I have to watch all the videos for my engineering mechanics class. And sometimes this class is not my top priority because it is easier. I want to do well in this class, but I have a mechanics class in which I am not doing that well so I want to apply more time towards that class. It is a struggle.
3. Perceived cost of the task: Students think that the time they need to spend on the modules is too long.	2	The modules are extremely time-consuming.

Program feedback.

All the participants considered the explanatory program feedback as one of the most valuable parts of the modules (the average rating is 5 out of 5) because the detailed immediate feedback presented on each step of problem solving helped them clarify their misunderstandings early in the process (see Table 5). All the participants found the feedback sufficient and did not need a more specific explanation (an adaptive feedback tailored to their response).

Table 5 Students' reflections on the feedback feature in the modules

Themes	Average rating	Supportive comments
1. Pre-determined explanatory feedback is the key part of the step by step problem solving practice in the modules	5	I like this part. I like this, the answer (pointing to the Immediate Feedback for each step in the Scaffolded Practice). I know that when I get something wrong and I cannot figure it out and it drives me crazy. Here (in the modules), it helps me understand where I made a mistake. It can be just one little thing, but if you cannot figure it out, you will do the same mistake over and over again. The feedback idea is huge!
2. The feedback in the modules is sufficient	5	I had online stuff like this when you put an entry. And it says "Wrong answer! Try again! Wrong Answer! Try again! And then it just gives the correct answer. So to have something like this (pointing to the feedback in the modules) is better. Because you do not learn anything from just the answer.

Instructional design strategies.

The presentation design of the modules follows from the properties of human working memory, as addressed in cognitive load theory (CLT) and Mayer's principles of design for multimedia learning (Mayer, 2001; Mayer & Moreno, 2003; Reed, 2006; van Merrienboer & Sweller, 2005). The themes from students' comments, the ratings for the implemented instructional strategies, and student supportive comments are presented in Table 6. The students found many instructional strategies and module features helpful. The participants were concerned with the length of some modules and specifically with the length of the videos presenting worked examples.

Table 6 Students' reflections on the instructional strategies implemented in the modules

Themes	Average Ratings	Student supportive comments
Scaffolded Practice with feedback allows one on one learning	5	1). Using Scaffolded Practice you teach yourself and proof yourself, and if you had more questions, the info on demand (it will be nice to have it for each step in the Long Problems) will cover most of them especially if you can click on the video chunk related to each step or problem in SP. Whereas if you do not understand one little thing you can email it to the instructor before you go to class or ask him in class. I am not a fan of watching long videos. 2). I can see a future for this. Because students who may need help do not need to go to the instructor and ask for help. This allows me one on one time. This may take time to design, but once the format is out it is a lot easier.
Step by step instruction is helpful	5	1). Step by step is huge. Sometimes the hardest part is starting the problem, maybe not necessarily with this class. But in a lot of classes, you just have trouble because with a problem, you know how to do it late on, and you are like, what is the first step? If you get a process down, it is kind of implanted in your brain. That really helps.
Presenting a set of formulas related to the problem on each screen is helpful	5	1). You look at this side and you see all the formulas. If you have a problem with this some time on the go, eventually, you will remember them. Whereas if he (the instructor in the other class) just uses numbers you might not remember the equation.
Presenting information in print helps with clarity	5	The instructor in the other online class goes through his explanations step by step, but the problem is that he has terrible hand writing. Not everyone can read it. This module is much better because everyone can read it.

Themes	Average Ratings	Student supportive comments
Presenting information on demand could be a nice addition to the program (have the info related to a particular question on each screen for those who need it)		That would help to have info on demand. If you are confused with the portion, you do not need to go back searching. That will be a lot better because it will reduce the time spent with the module. It takes too long.
Solving problems by yourself after watching worked out examples is helpful	5	I would like to be able to solve the problems not just see the instructor solving the problems. Because my brain does not work quick enough, I think, to catch everything what teacher says. They have been doing it 10-20 years and it is their second nature. They might not understand that for us it is still difficult.
Segmenting	5	Breaking up the information into chunks and steps helps retain it.
Font	4	1). I like the font. 2). It needs to be bigger
Having a range for the correct answer	5	It needs a certain range set. So, if your answer falls in to the range, it is correct enough to be considered as a correct answer.
Need for a better format of information presentation in the videos (worked examples)	3	1). Less zooming and going back and forward (I am focusing on the movement not on the instruction) 2). When I was watching Productivity Chains in Module 13, it needs more visualization, two minutes of steering on the screen is too much. It is beyond my attention span, but still good information.

Themes	Average Ratings	Student supportive comments
Some of the modules are too long	3	2). Please condense the modules, because it is a looooot!

Interaction usability.

Several navigation problems were detected when students were observed using the modules . Additional information about navigation problems came from the interviews with the students. The summary of the findings on the dimension of interaction usability is presented in Table 7.

Table 7 Summary of the findings on the dimension of interaction usability

Themes	Average Ratings	Supportive Comments
Students experienced problems with the navigation through the Module	2	*Observer comments*: 1). Four out of six students could not figure out that they should navigate through the Module using the NEXT and the BACK buttons. They were navigating through the Module by using the menu and that took them unexpectedly to other parts of the modules. 2). Two out of six students could not figure out the how the navigation path was supposed to work after watching the first video segment on video hosting service, ScreenCast. Those students were listening to the chunks of video in ScreenCast, one after another, and missed navigating to the comprehension questions between video segments. The students were supposed to return from ScreenCast to the module after each segment in order to answer the comprehension questions. 3). One student could not figure out that the screen with the video is expandable. *Student comments:* At first, I watched the videos one after another in Screencast, later I figured out that there are questions between videos. Those help to check your understanding of the material.

Students considered as an advantage the fact that the modules can be played on mobiles. See their comments in Table 8.

Table 8 Summary of students' comments on the accessibility of the modules on mobile devices

Themes	Average Ratings	Supportive Comments
1). Some students use ipads in class to watch the parts of the modules, others use smart phones to work on the modules during the break hours at work.	5	1). I saw people bringing their ipads and watch the parts of the modules online in class. I think that helps a ton. See, you cannot remember everything. You take notes, but it is nice to see the instructor doing it again. 2). When I have a break at work, I work with the modules on my smart phone.

Reusability: Addressing the needs of people with different learning styles.

The students were satisfied with the fact that the modules were designed to support the needs of students with different ways of information processing. Among six people, three people would rather use a combination of worked examples and step by step solution of the problems (Scaffolded Practice). Two people would rather use Scaffolded Practice and have some factual and conceptual information presented on demand on each screen when they need it for problem solving. One person would rather limit his use of the modules to worked examples and comprehension questions between the video segments. Students' comments about the versatility of the modules are presented in Table 9.

Table 9 Summary of students' comments on the reusability of the Modules by people with different learning styles

Themes	Average Ratings	Supportive Comments
Modules address the needs of students with different speeds and cognitive styles of information processing	5	1). I can use the modules at my convenience and at my own pace. 2). The modules allow students one on one learning. I am not a big fan of videos, step by step practice is better. They allow me to solve the problems by myself, proof myself, and learn faster.

Integration of the modules into the hybrid course.

The students raised their concerns about the integration of the modules into the course (see Table 10).

Table 10 Summary of students' comments on the integration of the modules into the course

Themes	Supportive comments
Feasibility of using modules on top of labs is questionable	1).Too many things going on in this class: you have the Modules, you have class problems, you have homework assignments, you have a lot to think about. It is overwhelming.
At the beginning of the semester, explanation of module benefits and demonstration of their use at is important	1).Explain to us how to go through it (the Module) so that we do not miss the quiz questions and use the arrows at the top right corner for navigation and we know that we just watch one video at a time on ScreenCast. 2).I would tell the students what is in the modules, why you have to do these modules and why it is beneficial to you.
The use of the modules will increase, if it is mandated.	1). If you want students to use the modules, student performance need to be graded. 2). The use of modules needs to be mandatory otherwise students will not use it.

Instructor's comments on students' progress through the course.

The summary of the instructor's comments about students' progress through the course is presented below. The instructor considered the modules as an effective way of learning. He said: "Students who were using the modules had a good experience with the modules and were well prepared for solving problems in groups during lab sessions." The instructor felt that the program helped the students learn systematically because students' exam grades during the semester were on average higher compared to the previous semesters. "The modules helped the students to look at the problems at their own pace with their individual backgrounds."

Even though the instructor did not question the educational value of the modules, he noticed that not all students used the modules. By the end of the semester, less than half of the class devoted enough time to work with the modules. The instructor found that the module design should be improved to do a better job motivating students to use them. He commented: " I do not question the educational value of the modules, but I do not know how to motivate students to use them on a regular basis."

Tracking of students' use of the modules.

The data about how students used the Modules came from the Blackboard course management system. They have shown that the students spent time using the Modules; however, there was no consistency with regard to how much time was spent with each module. During the interviews, some students indicated that they went directly to the Scaffolded Practice with feedback and skipped the videos. If they had trouble understanding the material, they went back to the parts of the videos they needed for clarification of the material and did not watch all the videos with worked examples. Fewer students limited their use of the modules to watching the videos only, and skipped the Scaffolded Practice.

Since the use of the modules was not required during the course (no points for the use of modules, the scores of students' correct/incorrect answers through the modules were not included in the calculations of student final grade), some students did not commit much time using them. In the first part of the semester, half of the class used the modules, by the end of the semester, only one third of the students used them on a regular basis.

Discussion and Conclusions

The main findings cover several topics of interest: engagement, effectiveness of a teaching approach, efficiency of the teaching approach, the appropriateness and user-friendliness of the overall multimedia design and separate features, flexibility, technology issues, time commitment issues related both to the module itself and integration in the course. The results of the evaluation reveal that the modules have several positive features such as teaching effectiveness of the modules, accessibility on mobile devices, and the ability to address the needs of students with different learning styles. The modules

1. Allow one on one training at students' own pace

2. Facilitate cognitive processing of the information

3. Allow high engagement with the material because of interactivity

4. Address students' differences in learning styles

5. Allow flexibility of interacting with the material

According to students' comments, the modules had an educational value because of the combination of worked out examples (video demonstration of problem solution) and step by step problem solving augmented with explanatory feedback. Also, the participants found chunking videos with comprehension questions as an effective method to help them monitor their understanding of the material.

Along with the positive features, a series of deficiencies was found that needed to be resolved. Some of these deficiencies are related to the navigation design of the modules, others to the way the modules were implemented during the course.

First, the navigation design of the modules allowed three paths: linear navigation by clicking on NEXT and BACK buttons, navigation to segments of the Module, and navigation within video hosting service ScreenCast. Without receiving explanations of how and why to use the modules, many students were confused at the beginning of the semester. These findings are in concert with the experiences of other instructors of hybrid courses.

One of the lessons learned by seventeen instructors during the Hybrid Course Project in five University of Wisconsin (UW) campuses was that "…students don't grasp the hybrid concept readily. Instructors need to provide repeated explanations about the model and why it was chosen for their particular course". Instructors must be aware of students' perceptions, especially that they don't consider a face to face lecture to be "work" but they definitely consider online activities to be "work." (Aycock, Garnham & Kaleta, 2002, p.2).

Second, the students perceived that the modules that took more than an hour of work were too long to be put on top of the existing traditional course. The common themes that arose from the informal conversations of the instructor and the teaching assistants with the students during the semester:

1. The modules are too long to use them as preparation for in-class sessions.

2. The students had trouble paying attention to the videos demonstrating worked examples and staying on task.

3. The modules were not required, and the students were not motivated to do extra work without reward points.

4. The students wanted to do the work once either at home online by using the modules or in class. They did not want to do the same work twice.

The above factors may have influenced students' navigation patterns (they used parts of the modules) and students' motivation to use them on a regular basis. This is in tune with the research findings. According the previous research, one of the most common problems with the design of hybrid courses is "course and a half" syndrome when "instructors tend to 'add-on' to their traditional course instead of rethinking their course's objectives with the Hybrid model in mind." (Aycock, Garnham & Kaleta, 2002, p.1). The authors of the article recommend the hybrid course designer to "identify what is not working in the face to face version and determine if there is way to do better in an online environment."(Aycock, Garnham & Kaleta, 2002, p.1).

Based on the analysis of tracking students behavior (grades for homework, test grades) and the conversations with the students, we found out that the modules were used by "A", "B", "C", and "D" students who needed time to process the information at their own pace and were willing to spend extra time on step by step instruction without receiving any benefits for their final grade or saving time by submitting course assignments from home and not coming to class.

Recommendations

The triangulation of the data allowed the researchers to propose the plan for the Module modifications.

1. Keep the step by step nature of the training through the modules (Scaffolded Practice).
2. Keep the explanatory feedback on each step of the Scaffolded Practice.
3. Reduce the length of the videos of worked examples (referred here as the Videos).
4. Put the Videos in an engaging multimedia format (narrated animation) with more cueing of the important information.
5. Place the segments of the Videos one segment per screen. Each segment describes how to work out one step.
6. Add a new feature that will allow students to visually and mentally combine separate steps of the Scaffolded Practice into a whole (it will help students see how each step fits into the big picture of a problem solution).
7. Add the demonstration of problem solving at the beginning of the course and explain the module benefits.
8. The research findings helped the researchers make final decisions about which parts of the hybrid course had a potential to be delivered online and which ones needed to be delivered in a face to face manner.

Study Limitations and Future Research

This paper presents pilot research. It was conducted on a small number of participants in a real instructional setting. The results of this study are preliminary. This research is the first step in a series of formative evaluations that will contribute to the refinement of the module design. The formative evaluations will be followed by the summative evaluation that will focus on the effectiveness of the modules and will be conducted on a larger sample of participants. The final step will be the implementation and evaluation of the framework to be used in the design of other hybrid engineering courses.

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Appendix A.

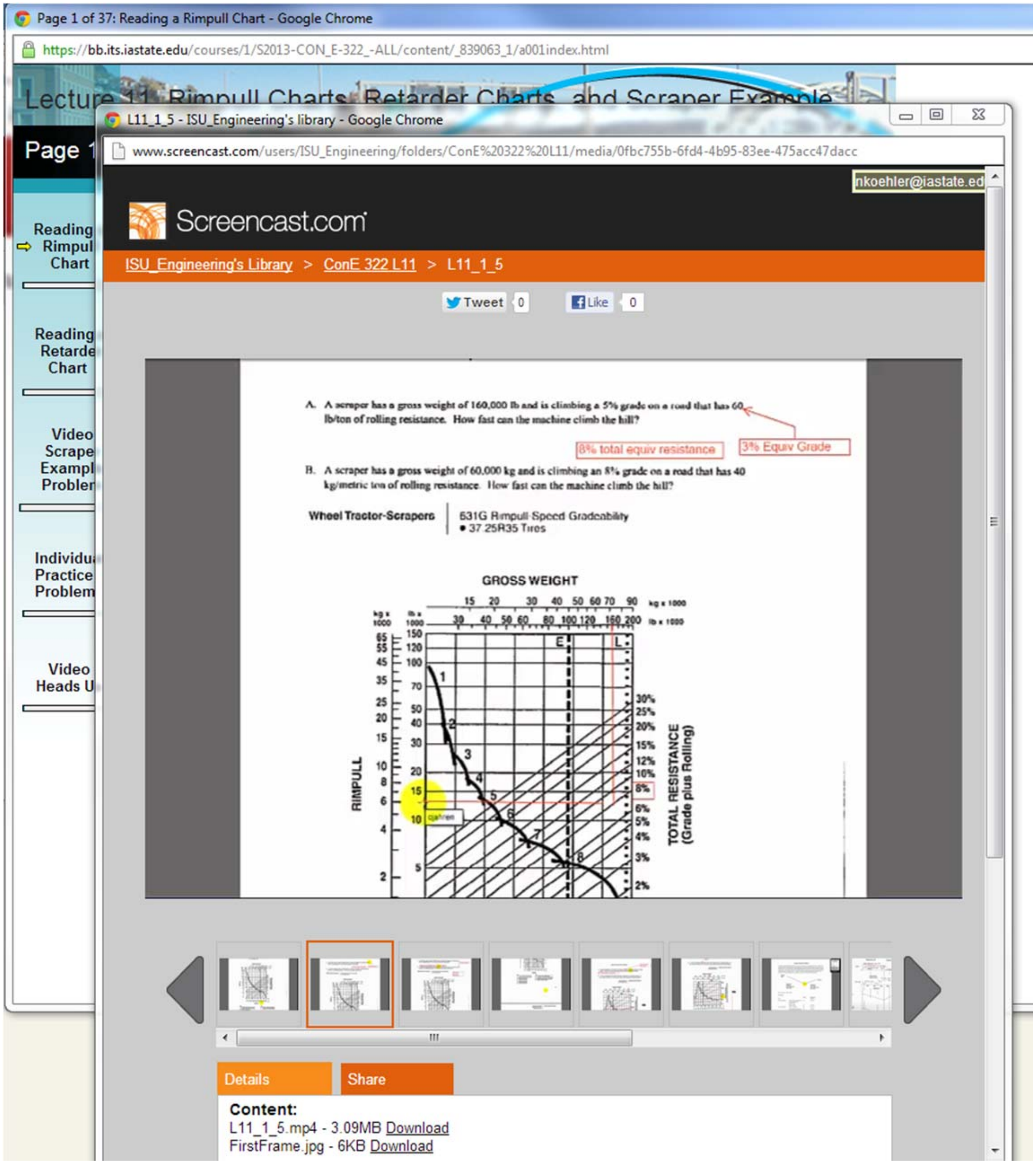

Fig 1 A screenshot illustrating the video demonstration of how to solve multiple step problems with definitive answers.

Fig 2 A screenshot demonstrating the problem scenario for the Bulldozer Example Problem that students need to solve in a step by step interactive learning environment.

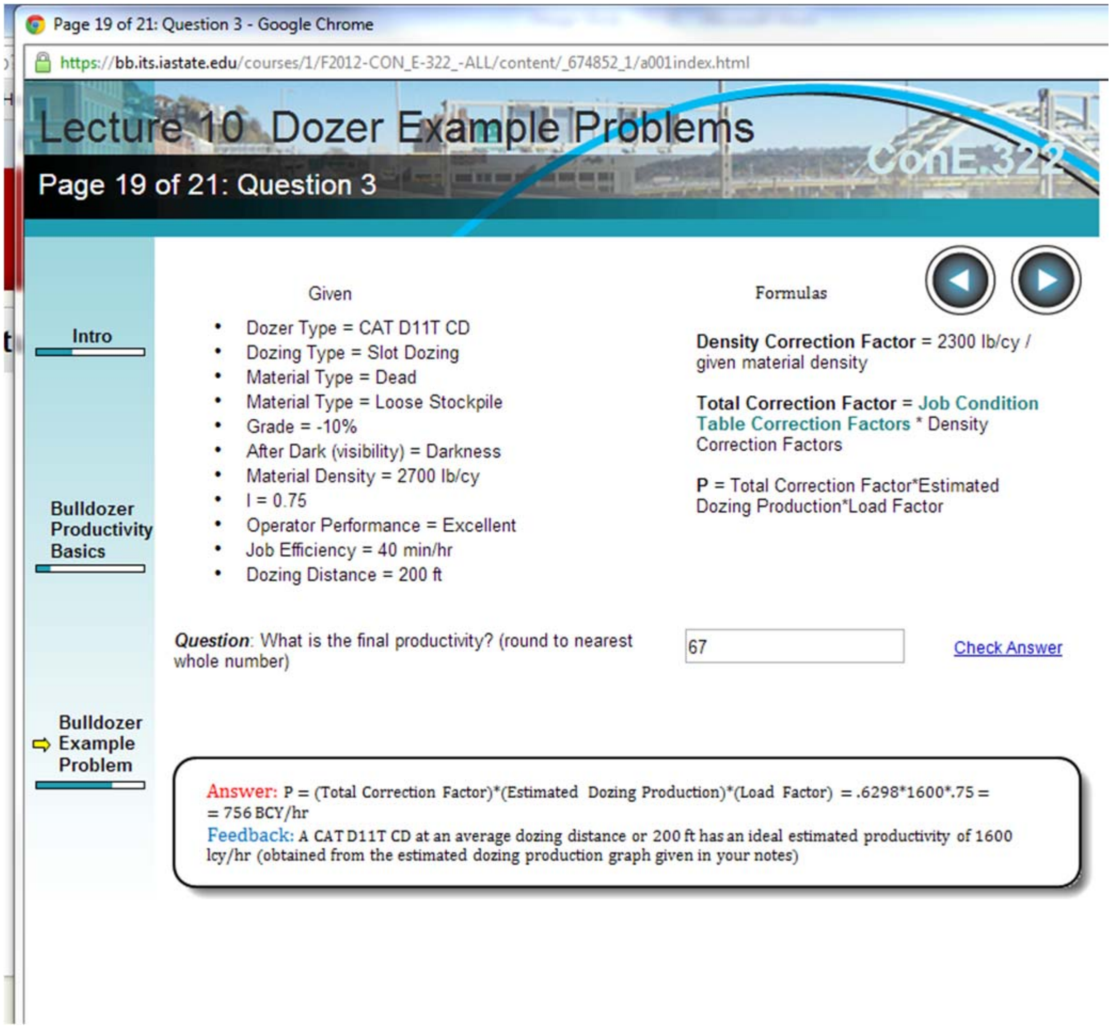

Fig 3 A screenshot demonstrating Step 3 for the Bulldozer Example Problem that students need to solve in a step by step interactive learning environment augmented with the explanatory feedback.

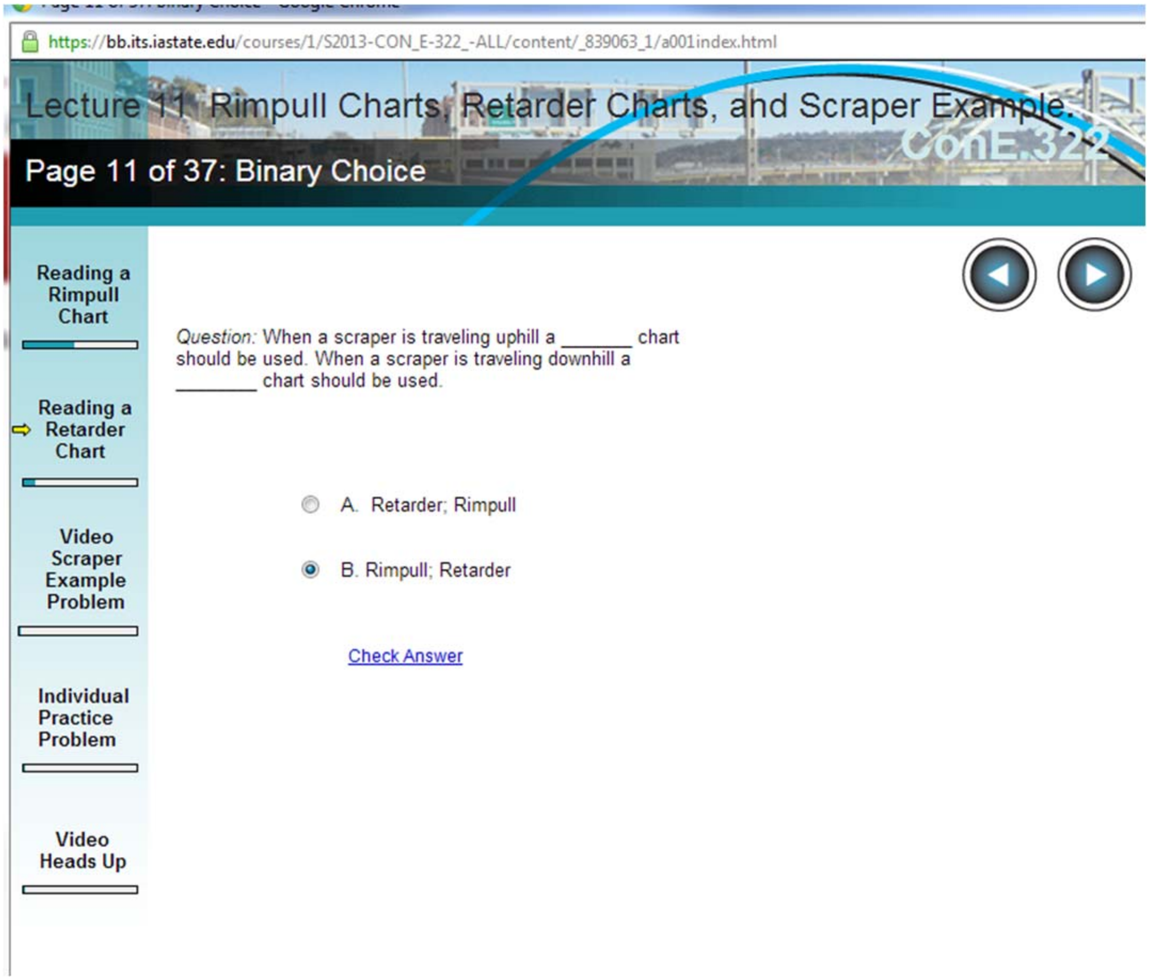

Fig 4 A screenshot demonstrating a comprehension question that students need to answer after watching the video chunk of the problem solution demonstration.

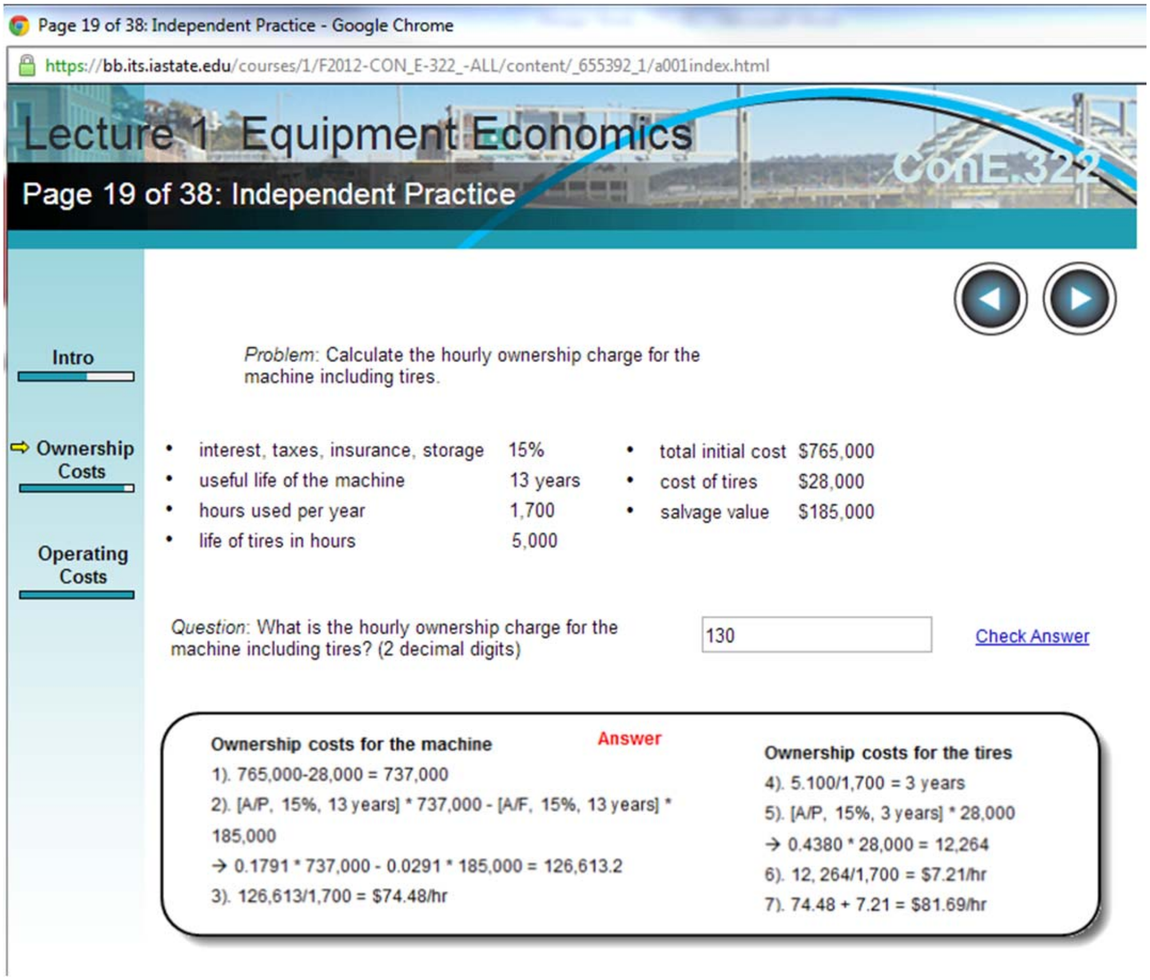

Fig 5 A screenshot demonstrating independent problem solving practice

Table 1. The cognitive processes dimension — categories, cognitive processes (and alternative names)

lower order thinking skills ⟶ higher order thinking skills

remember	understand	apply	analyze	evaluate	create
recognizing (identifying) recalling (retrieving)	interpreting (clarifying, paraphrasing, representing, translating) exemplifying (illustrating, instantiating) classifying (categorizing, subsuming) summarizing (abstracting, generalizing) inferring (concluding, extrapolating, interpolating, predicting) comparing (contrasting, mapping, matching) explaining (constructing models)	executing (carrying out) implementing (using)	differentiating (discriminating, distinguishing, focusing, selecting) organizing (finding coherence, integrating, outlining, parsing, structuring) attributing (deconstructing)	checking (coordinating, detecting, monitoring, testing) critiquing (judging)	generating (hypothesizing) planning (designing) producing (construct)

Fig 6 Revised Bloom's taxonomy. Table adapted from Anderson and Krathwohl, 2001, pp.67-68