A Detailed Process for Creating Multiple Choice Exams in a Mechanics of Materials Course

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Abstract

Multiple choice exams have been used in the Mechanics of Materials course at Missouri University of Science and Technology for the past three years. Over 1000 students in 17 course sections have participated in these exams. This paper describes the exam development process that has evolved over the past five years and, in particular, how Wimba Diploma, Respondus and Blackboard have been integrated to generate and administer the exams. To date, approximately 1800 short questions have been written and 240 have been processed with the software to create 2500 unique exam questions for use on both printed and electronic exams.

Introduction

Faculty, staff and students at Missouri University of Science and Technology have spent the last five years developing a streamlined evaluation process in the Mechanics of Materials course. The work began as an attempt to manage increasing section sizes and a decreasing number of instructors. Since 2002 the number of students per section rose from 30 to 110 and the number of faculty members teaching the course was cut in half. Table 1 summarizes how one instructor varied his exam format over this time period attempting to find a more efficient approach. After much effort, the authors feel that their current evaluation process is ready to be expanded to all of the sections in this course and to other courses.

In 1997 Peter Rosati[1] described his use of multiple choice questions in a Statics course. More recently, Neil Book and Oliver Sitton[2] have discussed the advantages and pitfalls of using computer-based assessment in engineering courses. Last year Joseph Coffman[3] and his colleagues described a method for creating and evaluating multiple choice quizzes and provided a checklist for question authors. The purpose of this paper is to describe the authors' experiences and lessons learned, with an emphasis on the question-authoring software they have used, in case someone wants to try it in his or her courses.

Background

Prior to 2006, the Mechanics of Materials course had a common schedule and common homework assignments. Instructors collected weekly written homework assignments and gave four in-class exams and a common final exam. The in-class exams typically consisted of four questions, and the final exams had eight questions. Each question required one-half to one full page of written work. All of the exams were graded by hand, and partial credit was given for partially-correct solutions. During the summer and fall of 2006 and the spring of 2007, the instructors experimented with a combination of short and long exam questions. Many of the in-

class exams and all of the final exams used in the fall of 2007 and thereafter consisted of 12 to 33 short questions. Shorter questions allowed the grading to be done in a timelier manner.

Semester	Students Per Section	Number of In-Class Exams	Number of Exam Versions	Questions on Common Final Exam
2002 Fall	24	4	1	8 long
2003 Spring	27	4	1	8 long
2003 Fall	32	4	1	8 long
2004 Spring	33	4	1	8 long
2006 Spring	56	4	1	8 long
2006 Summer	53	4	1	7 short, 5 long
2007 Fall	20	4	1	13 short, 1 long
2008 Spring	30	4	1	24 short
2008 Summer	39	7	1	23 MC
2008 Fall	60, 47, 49	7	4	27 MC
2009 Spring	30, 49, 90, 80	8	4	33 MC
2009 Summer	40	7	4	33 MC
2009 Fall	92, 85	8	8	31 MC
2010 Spring	102, 100	8	10	33 MC
2010 Summer	46	7	10	33 MC
2010 Fall	104	8	10	26 MC
2011 Spring	114	8	10	26 MC
2011 Summer	52	7	52	26 MC

Table 1. Summary of exam format changes for one instructor.

The short exam questions were modeled after those of the Fundamentals of Engineering exam administered by the National Council of Examiners for Engineering and Surveying. The primary guideline in creating these questions was to limit how far an error could propagate through a student's work, and therefore make it easier to assign partial credit, yet not make the questions too easy. The instructors began by examining the homework problems used in the course and dissecting them into pieces that typically require only one or three formulas to solve. Following this approach, teaching assistants then created approximately 100 exam questions per chapter.

Beginning in the summer of 2008, one instructor converted his exams to a multiple choice format with limited or no partial credit, and he has experimented with that format since. Multiple-choice was chosen over open-response because it more closely mimicked the homework solution process. Students work a homework problem, check their answers against the back of the book, and then look for mistakes if the numbers do not agree. With a multiple choice exam problem, students know to look for mistakes when their answer does not match any of the available choices. The authors have observed that students can often resolve calculation errors and small conceptual errors during an exam, reducing or eliminating the need for partial credit, but they can rarely resolve larger errors.

To deter cheating, four to ten versions of each exam were given. Originally, the versions had different questions, but, as the question-creation process matured, each version had the same questions but different numbers. Figure 1 shows a typical multiple choice exam covering two chapters–torsion and equilibrium of beams. It has 15 questions ranging in value from 3% to 8% each. A bubble answer sheet is included on the first page, and a formula sheet is included on the last page.

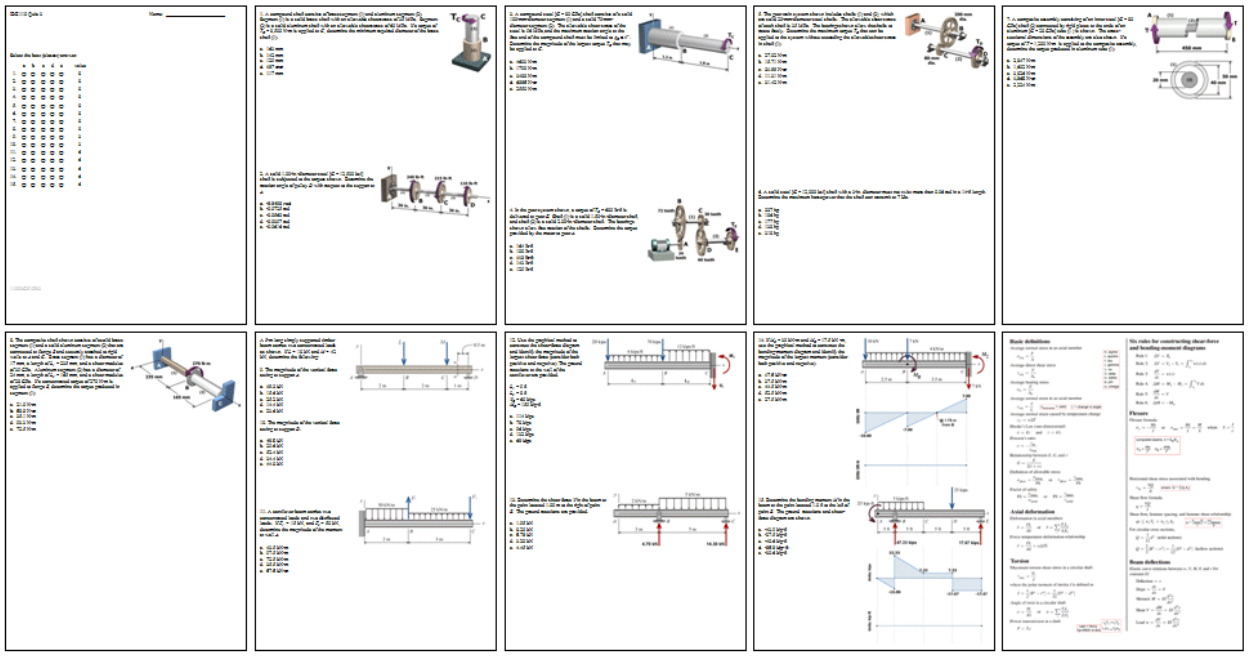


Figure 1. Multiple-choice exam covering torsion and equilibrium of beams.

A spreadsheet was used to streamline grading of these printed exams. Choices made by each student were manually entered into spreadsheet, which in turn provided statistics for each question and allowed scores to be more easily loaded into the course-management software.

During the summer of 2011, the exams were administered and evaluated using Blackboard. Students met in a single computer lab, were given packets of blank paper and a common formula sheet, and took the exam at the same time. They were allowed to access their score as soon as they finished the exam, with the instructor sometimes adding a curve to the scores later in the day.

Question-Creation Methodology

The multiple choice questions were derived from problems in the first edition of Dr. Timothy Philpot's book entitled Mechanics of Materials: An Integrated Learning System (Wiley, 2008). He graciously provided access to all 955 of the homework problems in Word format. Figure 2 shows how the 764 problems that directly related to topics covered in the course were divided into 1812 questions more suitable to multiple choice. Each question was sorted into one of 220 question categories. The course has 12 terminal learning objectives and 132 enabling objectives,

and the question categories were mapped to the enabling objectives. The instructors hope to further examination the relationship between enabling objectives and question categories, come up with a one-to-one match, and then map them to the terminal objectives and ABET program outcomes.

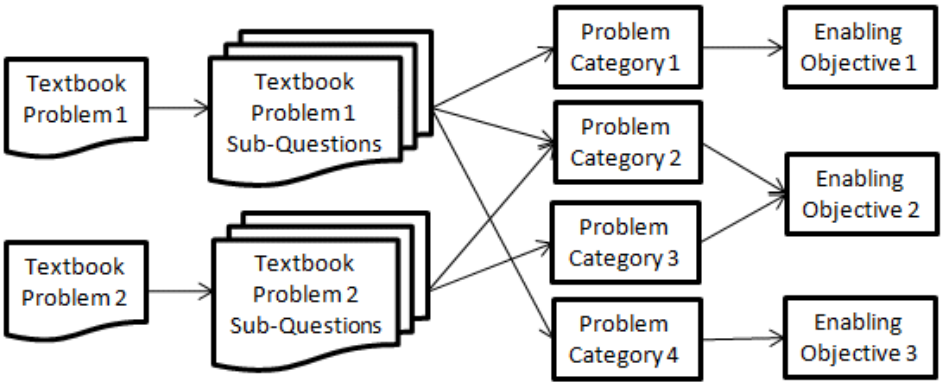
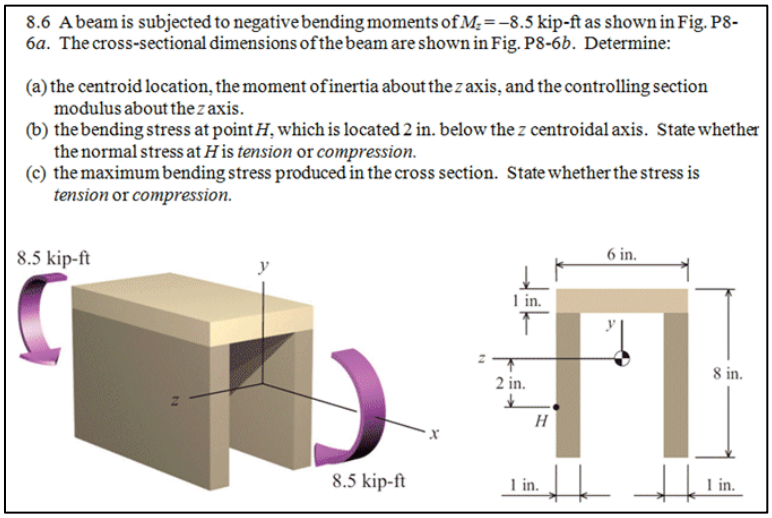


Figure 2. Creating and sorting multiple choice exam questions.

Figure 3 shows a typical homework problem related to bending stress. The problem can easily be divided into the following exam questions. (1) Find the centroid location. (2) Given the centroid location, find the area moment of inertia. (3) Given the centroid location and area moment of inertia, find (a) controlling section modulus, (b) bending stress at a particular point, (c) maximum bending stress, (d) maximum tension bending stress, and (e) maximum compression bending stress. Note that most of these questions were asked for in the original problem statement. To create multiple versions of questions 1 through 3a, one or more of the cross-sectional dimensions would need to be defined as a variable. To create multiple versions of questions 3b through 3e, the bending moment could be defined as a variable. Both options require minor alterations to the artwork.


8.6 A beam is subjected to negative bending moments of $M_z = -8.5$ kip-ft as shown in Fig. P8-6*a*. The cross-sectional dimensions of the beam are shown in Fig. P8-6*b*. Determine:

(a) the centroid location, the moment of inertia about the *z* axis, and the controlling section modulus about the *z* axis.
(b) the bending stress at point *H*, which is located 2 in. below the *z* centroidal axis. State whether the normal stress at *H* is *tension* or *compression*.
(c) the maximum bending stress produced in the cross section. State whether the stress is *tension* or *compression*.

Figure 3. Typical bending stress homework problem.

Figure 4 shows a similar homework problem related to bending stress. In addition to the questions just identified, one could ask the following statics questions: (4) Find the ground reaction at point *B*. (5) Find the ground reaction at point *D*. (6) Find the maximum shear force in the beam. (7) Find the maximum bending moment in the beam. (8) Find the shear force at a particular location along the beam. (9) Find the bending moment at a particular location along the beam. With no numbers listed in the original problem statement, cross sectional dimensions, loads, and/or beam lengths would need to be varied in order to create multiple versions of these questions.

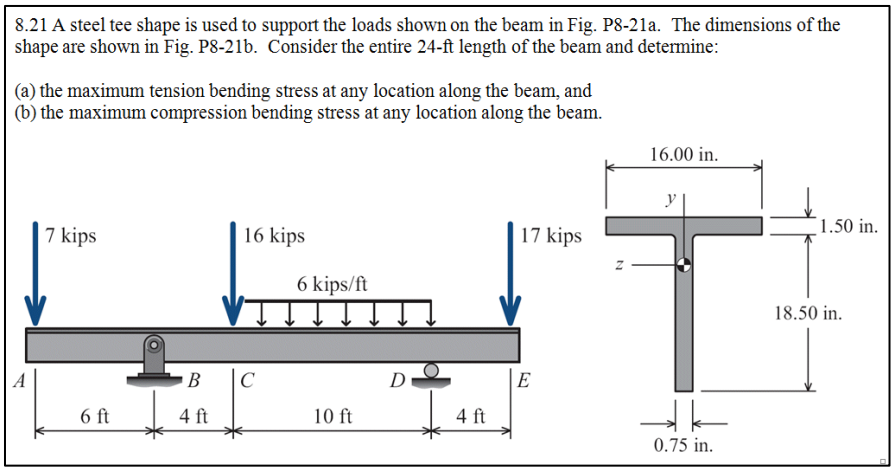


Figure 4. Another bending stress homework problem.

Figure 5 shows a collection of questions related to centroid location. The authors defined this as Category 8.2, corresponding to the eighth chapter and second type of question found in that chapter. Note that the cross sections shown in Figures 3 and 4 appear in this collection.

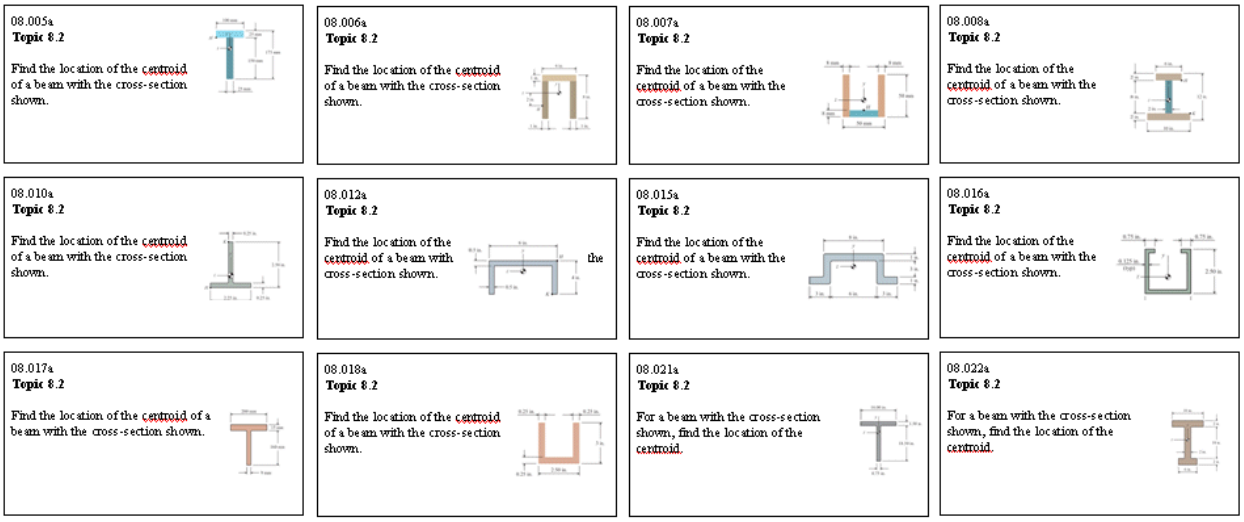


Figure 5. Questions in the centroid-location category.

Figure 6 shows a small portion (Category 1.5—direct shear stress) of a spreadsheet used to track the names and types of questions in each category. The middle portion of the spreadsheet shows whether the question has been pulled from the collection, rewritten with variables in Word, and processed with Excel, Wimba Diploma, Respondus and/or Blackboard to create variations with unique numbers. Whether (and where) the question has been used on an exam is highlighted on the right side. This allows the instructor to see how recently a particular question was used and make sure the types of questions change from semester to semester.

Problem Category				Available Problems	Word	Excel	Diploma	Respondus	Blackboard	Variations	Summer 2011	Spring 2011
1.05	direct shear stress	bolts & pins	single	01.015a								
				01.016a	X	X	X	X	X	20		3
			double	01.013a	X	X	X	X	X	20		4
				01.014a								
				01.017a	X	X	X	X	X	20	6	
				01.018a	X	X						
				01.022a								
		glued joints	plates	01.012a	X	X	X	X	X	20	7	
				02.009b			X	X	X	12		
			pipes	01.020a								
				01.020b								
				01.025a								
		punch		01.019a								
		key										

Figure 6. Spreadsheet used to track question development and usage.

A variety of issues were resolved in the first couple of years of giving multiple choice exams. These issues involved how many questions could be completed in 50 minutes, how many distractors to use, how to create the distractors, and whether to assign partial credit for distractors based on common mistakes. During this time period, the correct answer for each question variation was generated in Excel, and the exams were assembled in Word. Distractors were typically the correct answers to the other variations, which made sure the distractors were incorrect but reasonable choices.

This painfully manual process created additional issues of how to randomize the location of the correct answer, how to assemble the different versions of each exam, how many versions to give, how to print and pass out the versions so that students sitting side-by-side would not end up with the same version, how to link each version with its corresponding grading key after the exam, and how to determine and post the grades.

It commonly required 15 to 20 hours to create an exam two hours to grade it, and one hour to analyze and post the results. Preparation time went into picking approximately 15 questions, writing several versions of each, modifying images to have variables instead of numbers, calculating one correct and four incorrect answers for each version, checking whether the exam could be worked in 50 minutes and revising if necessary, sorting the printed copies for random distribution, and preparing the keys. This was much more time intensive than the traditional approach of picking and working four textbook questions. However, the preparation time was fairly independent of the number of students, grading time was greatly reduced, and cheating was

nearly eliminated, at least as far as the instructor could deduce. Students were told ahead of time that their chance of sitting near someone with the same exam was small.

Based on the lessons learned in 2008-2009, the authors' efforts turned towards finding a more automated way of creating question variations, assembling the exams, and posting scores. Figure 7 shows the resulting process. Questions are fed into Wimba Diploma and then Respondus or directly into Respondus depending on how the question is varied. Figure 8 shows a *non-algorithmic* question that has no numbers or variables in the problem statement but, instead, uses a different image in each variation. Questions like this can be directly imported to Respondus. *Algorithmic* questions, like those derived from the homework problems in Figures 3 and 4, are first passed through Wimba Diploma in order create different numbers for each variation.

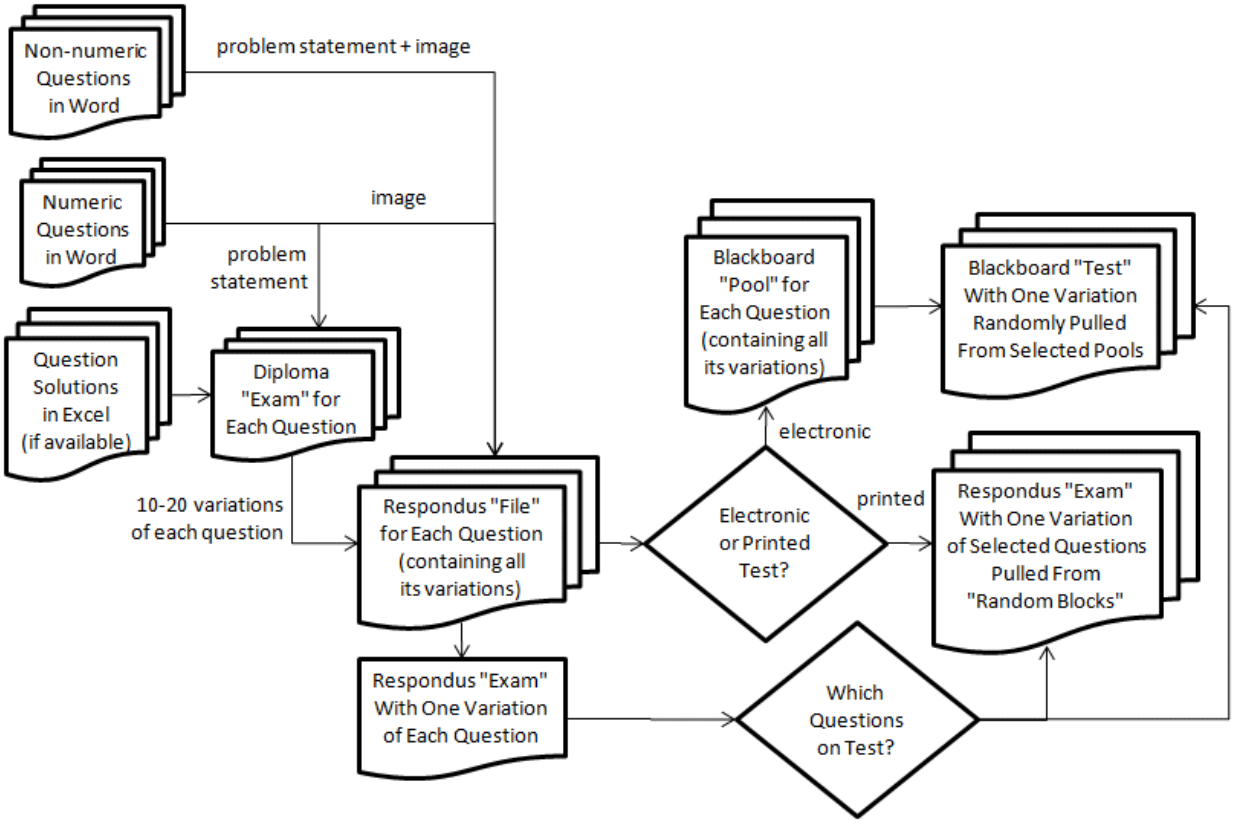
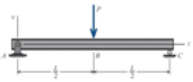


Figure 7. Current exam creation process.

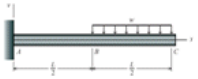
Respondus is used to pass the questions to Blackboard and to create two different kinds of Word files. One Word file contains one variation of each question available for a particular exam. The instructor uses this file to select the questions he wants to put on the exam, similar to the traditional method of looking through a textbook to find exam questions. Figure 9 shows a sample of this type of file. The second Word file is the actual exam. Respondus can create up to ten versions of the printable exam and their associated grading keys. Step-by-step instructions of how Wimba Diploma, Respondus, and Blackboard have been used are contained in the following sub-sections.

1. For the loading shown, find the equation of the bending moment for section *BC* of the beam. Assume that *EI* is constant for the beam and that the origin is at *A*.



a. $M(x) = PL/2 + Px^2/2$
b. $M(x) = -PL/4 + Px$
c. $M(x) = Px/4 + P/2$
*d. $M(x) = -Px/2 + PL/2$
e. $M(x) = Px^2/4 - Px/2$

2. For the loading shown, find the equation of the bending moment for section *AB* of the beam. Assume that *EI* is constant for the beam and that the origin is at *A*.

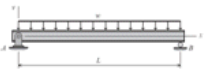


a. $M(x) = -wLx/2 + 5wL^2/8$
b. $M(x) = wLx^2/6$
c. $M(x) = wx^2/3 - 2wL^2/3$
*d. $M(x) = wLx/2 - 3wL^2/8$
e. $M(x) = -wL^2/2 + 3wx^2/5$

3. For the loading shown, find the equation of the bending moment for section *CD* of the beam. Assume that *EI* is constant for the beam and that the origin is at *B*.

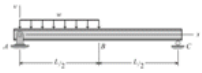
*a. $M(x) = Px - 5PL$
b. $M(x) = -6PL + Px$
c. $M(x) = -PL - 2Px$
d. $M(x) = PLx - 4x^2$
e. $M(x) = -PL + 5Px$

4. For the loading shown, find the equation of the bending moment for section *AB* of the beam. Assume that *EI* is constant for the beam and that the origin is at *A*.



a. $M(x) = wx^2/4 - wLx/2$
b. $M(x) = -wx^2/2 + wLx/5$
c. $M(x) = wL^2/5 - wL/3$
*d. $M(x) = -wx^2/2 + wLx/2$
e. $M(x) = wx^2/3 - wx^3/2L$

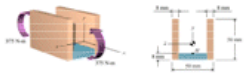
5. For the loading shown, find the equation of the bending moment for section *AB* of the beam. Assume that *EI* is constant for the beam and that the origin is at *A*.



a. $M(x) = wx^2/4 - wLx/2$
b. $M(x) = wL^2/8 - wLx/8$
c. $M(x) = -wLx/2 + 5wL^2/8$
d. $M(x) = wLx^2/6$
*e. $M(x) = -wx^2/2 + 3wLx/8$

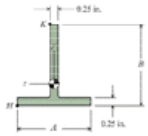
Figure 8. Sample non-algorithmic question.

08-007e
For a beam with the cross-section shown and loaded as shown, find the magnitude of the maximum bending stress in the beam. The moment of inertia about the *z* axis is 257,600 mm^4, the centroid of the section is located 19.67 mm from the bottom surface of the beam, and M = 650 N-m.



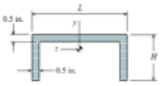
a. 76.5 MPa
b. 96.7 MPa
c. 62.9 MPa
d. 109.8 MPa
e. 54.0 MPa

08-010b
For a beam with the cross-section shown, find the moment of inertia about the *z* axis. The centroid of the section is located 0.8125 in. from the bottom surface of the beam. A = 2.50 in. and B = 2.75 in.



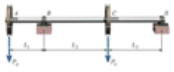
a. 0.920 in.4
b. 0.382 in.4
c. 0.898 in.4
d. 0.673 in.4
e. 0.500 in.4

08-023a
For a beam with the cross-section shown (L = 17 *in*, H = 5 *in*), find the distance from the bottom surface of the beam to the centroid.



a. 3.88 in.
b. 3.33 in.
c. 4.77 in.
d. 2.12 in.
e. 5.37 in.

08-026
A 18-mm diameter solid steel shaft supports loads P_A = 1,400 N and P_C = 2,100 N as shown. Assume L_1 = 100 mm, L_2 = 200 mm, and L_3 = 150 mm. The bearing at B can be idealized as a roller support and the bearing at D can be idealized as a pin support. The moment of inertia of the shaft is 5,153 mm^4. Determine the magnitude of the maximum bending stress in the shaft.

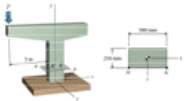


a. 244.5 MPa
b. 275.1 MPa
c. 256.6 MPa
d. 233.2 MPa
e. 288.4 MPa

08-047a
Two steel [E = 30,000 ksi] plates are securely attached to a Southern pine [E = 2,500 ksi] timber to form a composite beam. Find the moment of inertia of the equivalent all-wood beam.

a. 6,582 in.4
b. 7,838 in.4
c. 5,610 in.4
d. 9,690 in.4
e. 4,215 in.4

08-054a
If P = 180 kN, determine the normal stress produced at point H of the pier support shown.



a. –57.6 MPa
b. –46.4 MPa
c. –71.5 MPa
d. –81.0 MPa
e. –28.9 MPa

Figure 9. Questions ready to be used on a printed or electronic exam.

Wimba Diploma

Wimba Diploma is a question and exam authoring tool. It is limited to one-part questions where the variables are defined in the problem statement—not the image. The narrative in this section refers to software version 6.69. The basic interface is shown in Figure 10.

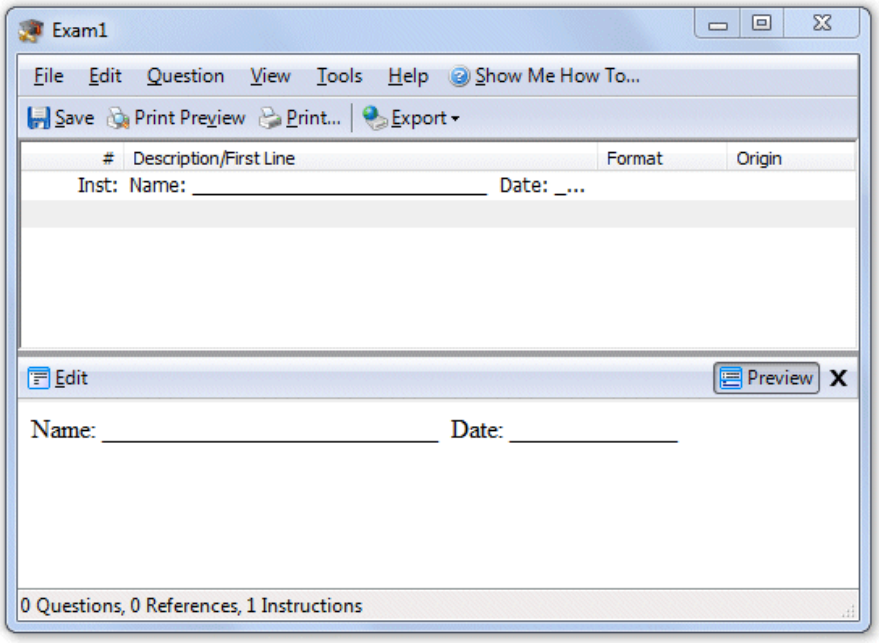


Figure 10. The Wimba Diploma interface.

Figure 11 shows an ideal question for use with Diploma. It contains several numerical values in the problem statement, and the image is labeled with symbols. Here, the original textbook problem had static variables of G = 350 kPa, P = 900 N, a = 15 mm, b = 50 mm, and c = 80 mm.

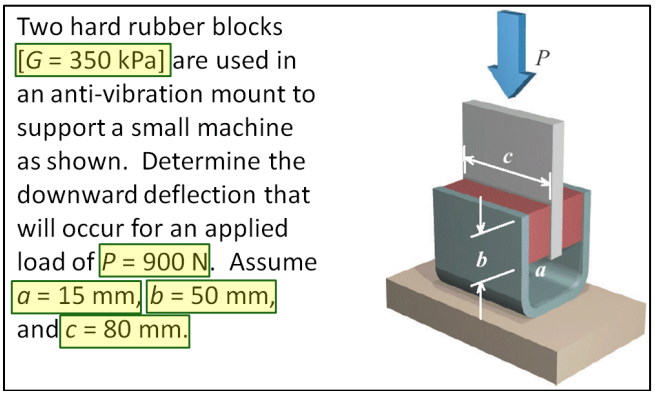


Figure 11. Example question suited for Wimba Diploma.

In Wimba Diploma, the authors follow these steps in order to create variations of the question:

1. Open a New Exam, and delete the default Instructions.
2. Select Question, New Question and specify a Multiple Choice format with 5 answers. Other question types, such as multiple selection, true/false, matching, fill-in-the-blank, short answer, and essay, are also available.
3. Select Edit to open the question window.
4. In Word, make sure any Greek characters in the question statement are in Symbol font, instead of Times New Roman Greek. Otherwise the formatting in Blackboard will be off.
5. Copy the problem statement from Word into the question window. Do not copy the image. The authors have discovered that images copied into Wimba Diploma and then passed through Respondus do not successfully make their way into Blackboard. Instead, the images must be added in Respondus.
6. Change the numbers to variable names. For example, change "*G* = 350 kPa" to "*G* = G kPa."
7. Highlight the new variable name, and hit F12 to define it as a variable.
8. The variable will now be available in the Variables tab. Change the variable type to Range-Based Variable.

For this question one could define the variables as follows and obtain 11 x 11 x 11 x 11 = 14,641 possible questions.

G = 250 to 350 kPa in increments of 10 kPa = 11 possible
P = 850 to 950 N in increments of 10 N = 11 possible
a = 10 to 30 mm in increments of 2 mm = 11 possible
b = 40 to 60 mm in increments of 2 mm = 11 possible
c = 80 mm

One would continue the process by doing the following.

9. Select choice *A* as the correct answer. The option to randomize the correct answer location will be selected later in Respondus.
10. Define a variable, such as *Ans*, in answer *A*'s placeholder. Highlight the variable, hit F12, and define it as an Equation-Based Variable.
11. Copy the solution formula from Excel, if available, and change its variable names to those defined above. A variety of function-based variables, such as Math, Trig, Finance, String, and User-defined, and conditional and feedback statements are available if needed.
12. Define variables for the distractors in a similar fashion. A variety of techniques can be used to assign numerical values to the distractors. A simple approach is to add or subtract a random number, within a limited range, to/from the correct answer. Another approach is to use a different set of input variables for the distractors. For example, let *G-incorrect-1* = 250 to 350 kPa but *Disallow* it from having the same value as *G*.

Great care should be taken to ensure there are no formatting differences between the correct answer and the distractors. Otherwise a student might be able to deduce the correct answer

without actually working the question. These differences would become especially obvious if a student were to view the source code of a browser window during a Blackboard test. An extra piece of HTML code on the distractors but not the correct answer, or vice versa, can expose the correct answer.

Figure 12 shows how the example question would appear at this point. With the variables now defined, one can select Solve Variables to check whether the question works correctly. Figure 13 shows how the variable names are temporarily replaced by numbers each time Solve Variables is selected. At this point one can check the answer using the Excel file, if available.

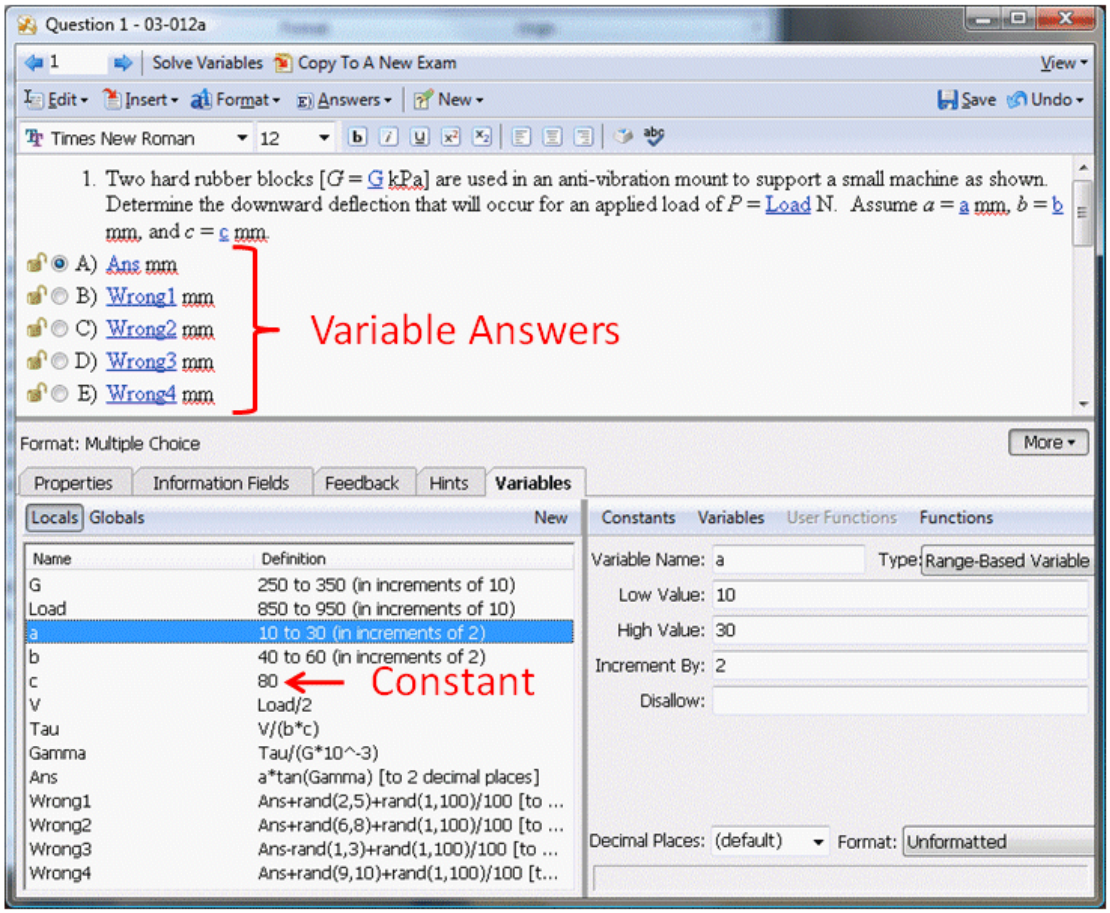


Figure 12. Example question with variables defined.

The process is completed by performing the following steps.

13. Under the Properties tab, fill in the Description with the question title. For example, the title "11.051d" corresponds to chapter 11, homework problem 51, exam-question *d*. Doing this will allow one to more easily identify the questions once they are in Respondus.
14. Close the Edit window.
15. Save the question as an *Exam*.

16. Copy and paste the question 10 to 20 times to create varied questions. The pop-up window shown in Figure 14 will appear. Select the Create Duplicates option.
17. Export to IMS-QTI 1.2. The variables become fixed or static upon export.
    a. In the Export window, select Change…
    b. As seen in Figure 15, select the Source of the question title to be the Description.
18. Unzip the exported XML files. Manifest.XML is a generic file and can be ignored. The remaining XML file is ready for import to Respondus. On a side note, exporting directly from Wimba Diploma to Blackboard will result in a Blackboard Test. Instead, Respondus will export the question variations to Blackboard as a Pool, which is the desired outcome.

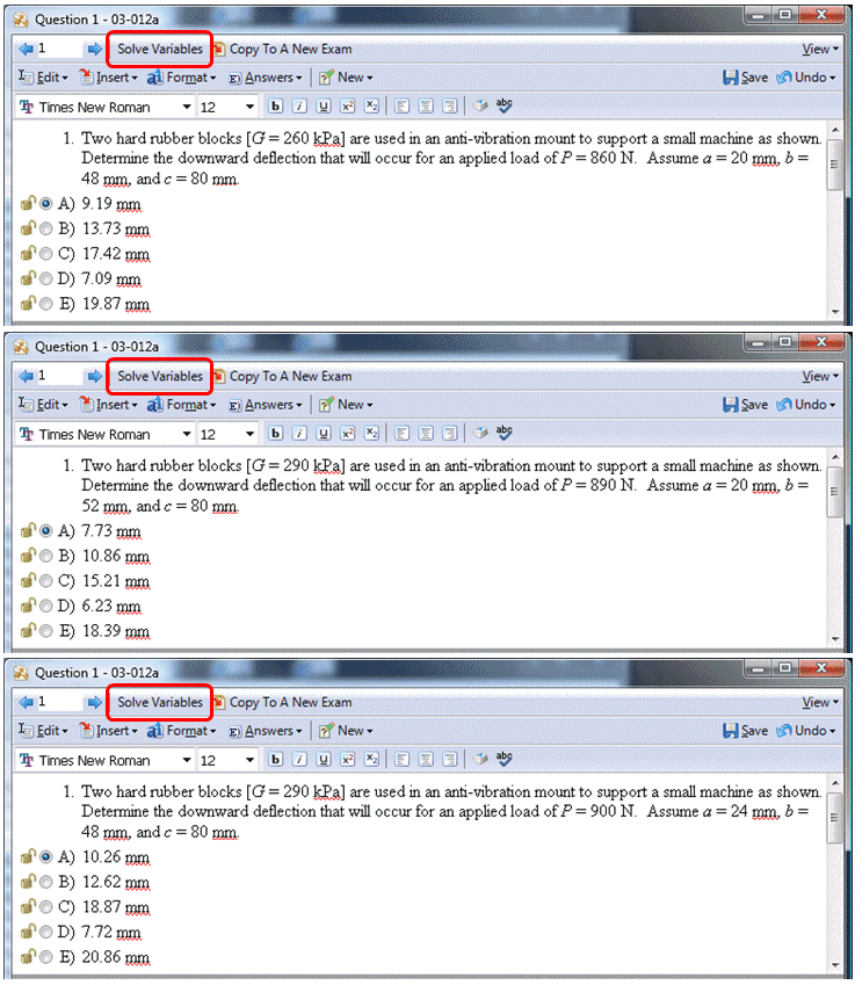


Figure 13. Using Solve Variables to check solution.

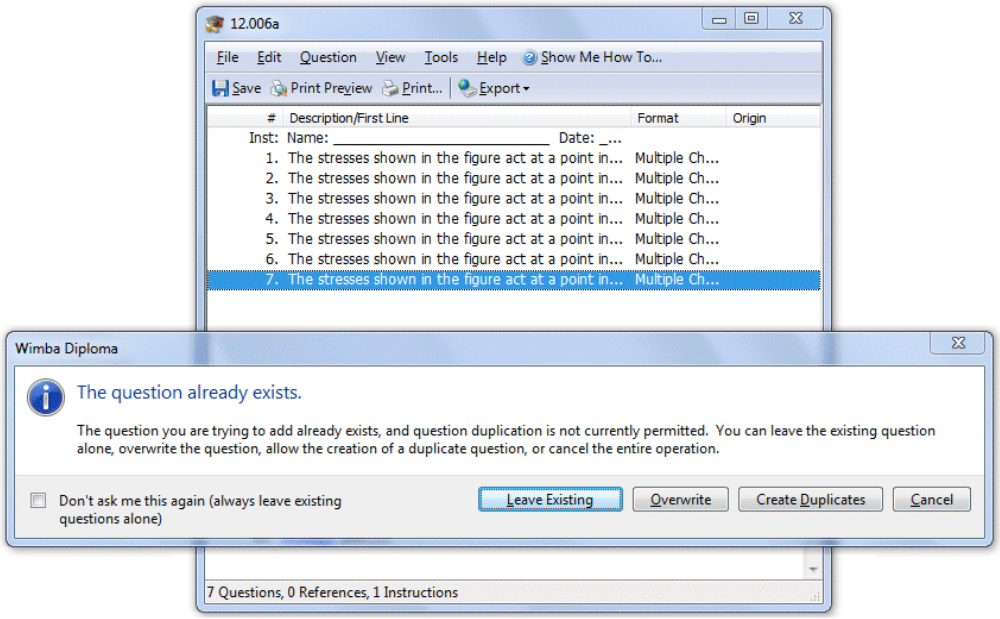


Figure 14. Copy-and-paste the question to create variations.

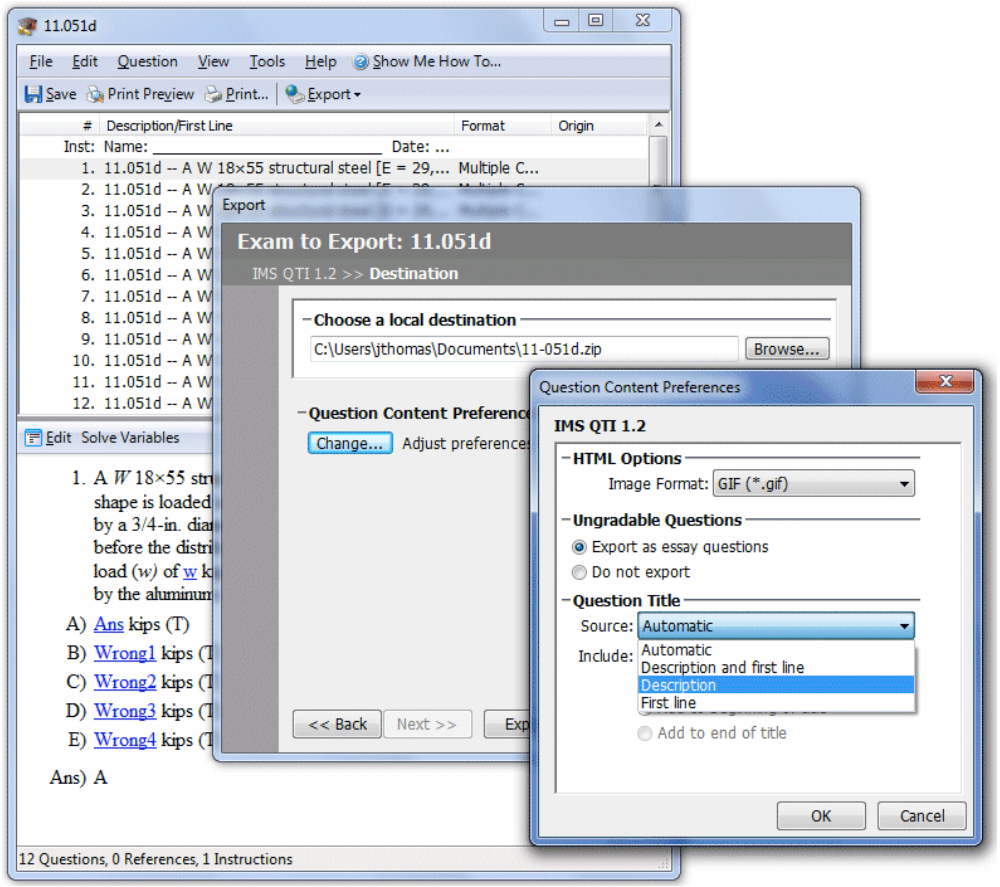


Figure 15. Export to IMS QTI format.

Respondus

Respondus is a question authoring program similar to Wimba Diploma. It is not as sophisticated in terms of defining variables and generating question variations, but it integrates better with Blackboard in terms of Pools, Tests, and other test options. It is also more sophisticated in terms of printing options. The narrative in this section refers to software version 4.0.

In Respondus, the authors follow these steps in order to prepare the questions for export to Blackboard:

1. In the Start tab, change the *personality* to IMS QTI. Personality refers to the learning management system configuration for question format.
2. Import the XML file created in Diploma. Figure 16 shows the "Create a new document" option that needs to be selected. Select Preview and then Finish.
3. Change the personality to Blackboard 6.3-9.x.
4. In the Preview and Publish tab, one can Preview the File to see the imported questions. Note that they still lack images.
5. Go to the Edit tab and insert the image in the first question variation, adjust the formatting as necessary, and select the Randomize Answers option. If Randomize Answers is not selected, the correct answer will always show up as choice *A* in Blackboard.
6. To avoid formatting issues, such as hard returns before and after each Greek symbol, with Blackboard tests, the authors have found it necessary to delete any special characters that were created in Diploma and then add them back with Respondus Power Edit. This is time consuming but more efficient than trying to resolve the issue once the questions are in Blackboard.
7. Be sure to Save Changes before moving to the next question variation. Figure 17 shows a Preview of what the question looks like at this point.
8. Edit the remaining question variations in the same manner. Remember to Save Changes after each one.
9. Go to the Preview and Publish tab and select the Publish to Blackboard option. Figure 18 shows the Create New Pool option being selected.

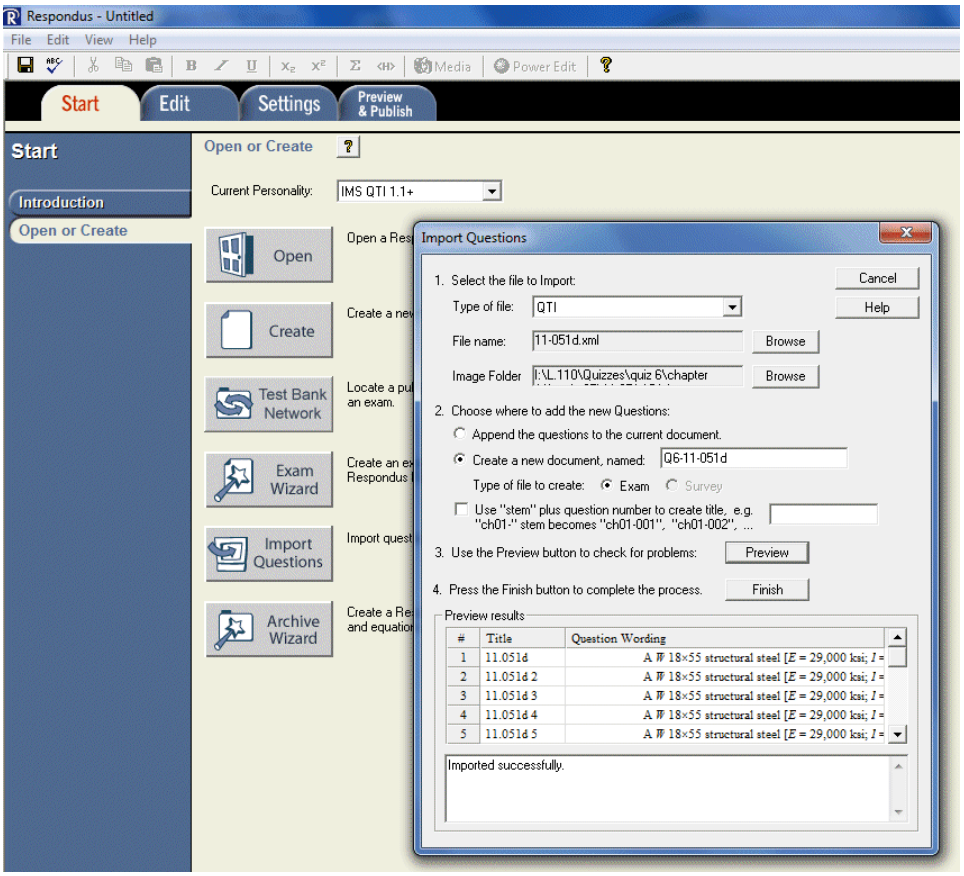


Figure 16. Importing IMS QTI files to Respondus.

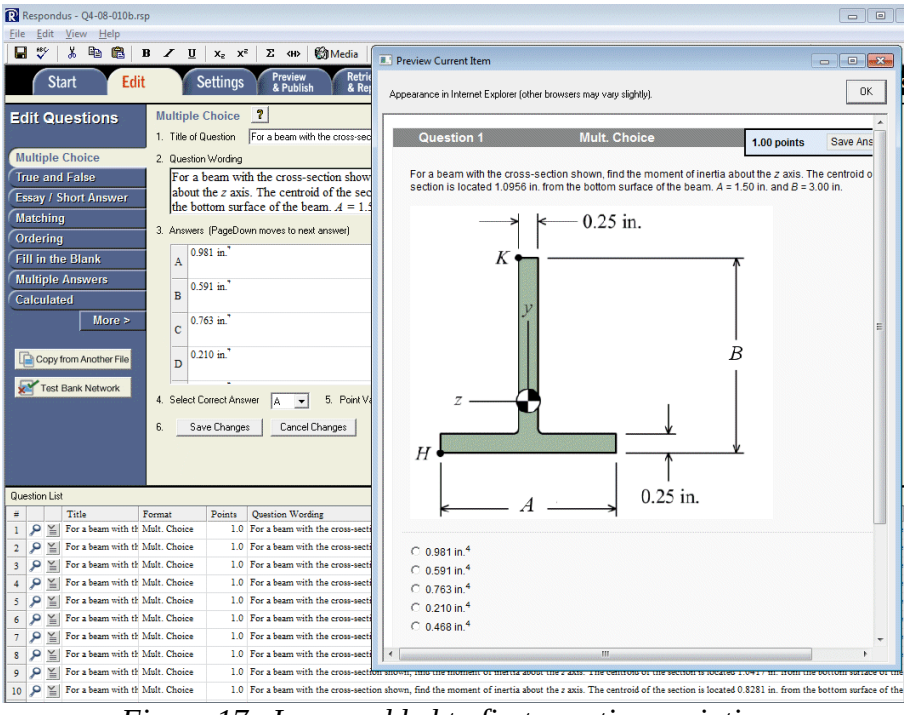


Figure 17. Image added to first question variation.

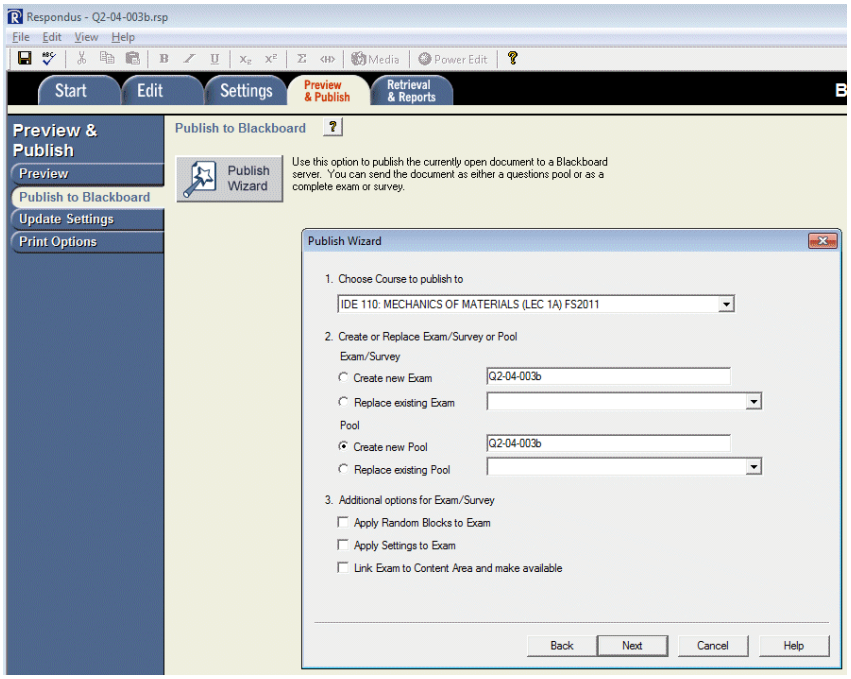


Figure 18. Exporting to Blackboard.

To print a sample of all the available questions, one would do the following.

1. Go to the Start tab and select the Exam Wizard, even though the desired outcome is not an *exam* per se.
2. Select each available question as shown in Figure 19.
3. Select Next, and add one variation of each question to the End of List as shown in Figure 20.
4. Go to the Print and Preview tab and select Print Options. As shown in Figure 21, one can adjust the Exam format, preview it, and save it as a Word document.
5. As seen in Figure 22, the authors often open the file in Word, reduce the margin size to 0.5 inches, increase the font size to 26, add a border to each page and then print 16 pages per sheet of paper. This saves a lot of paper and speeds up the question selection process by being able to view several problems at once.

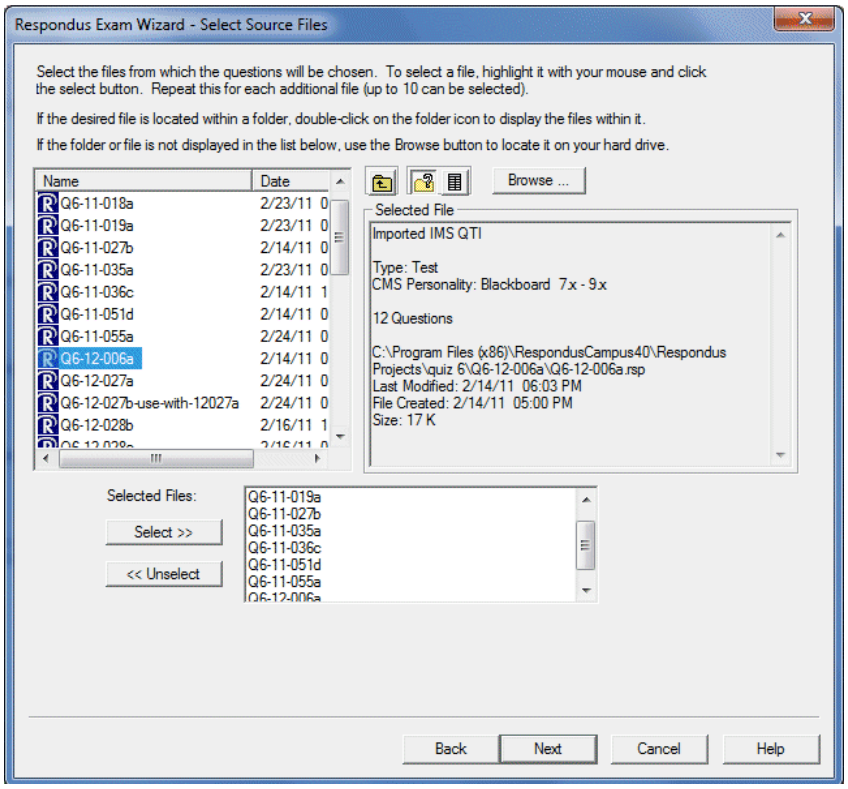


Figure 19. Selecting questions to be printed.

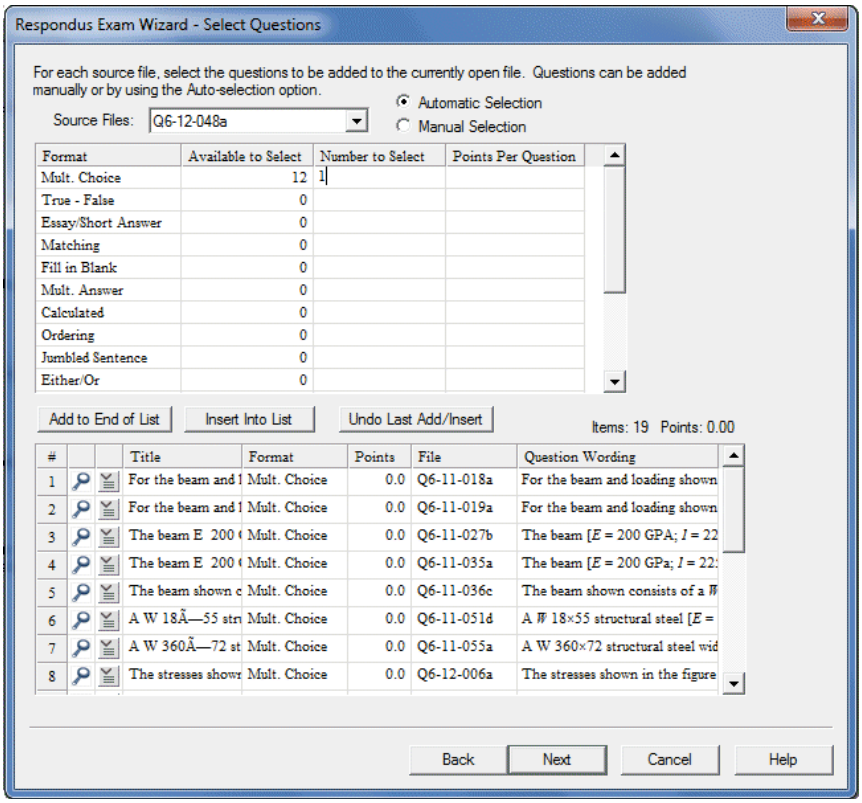


Figure 20. Adding one variation of each question.

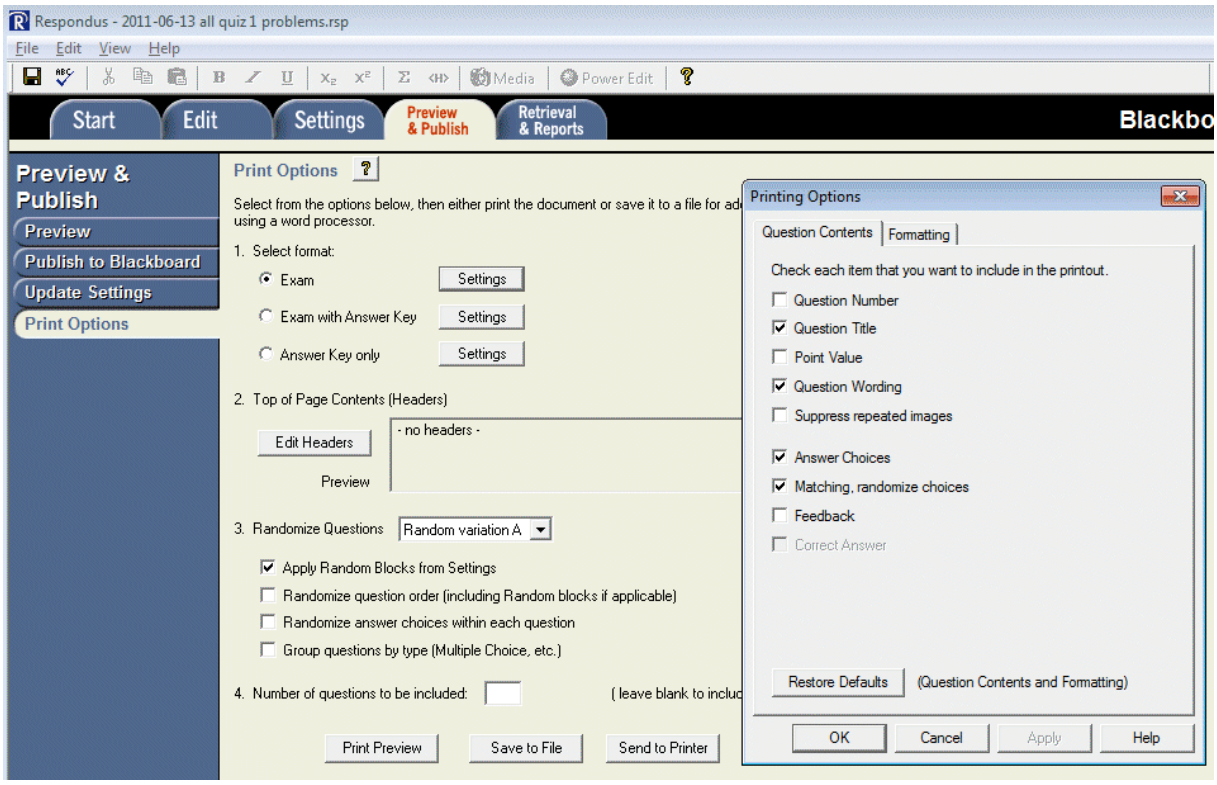


Figure 21. Formatting the Word file.

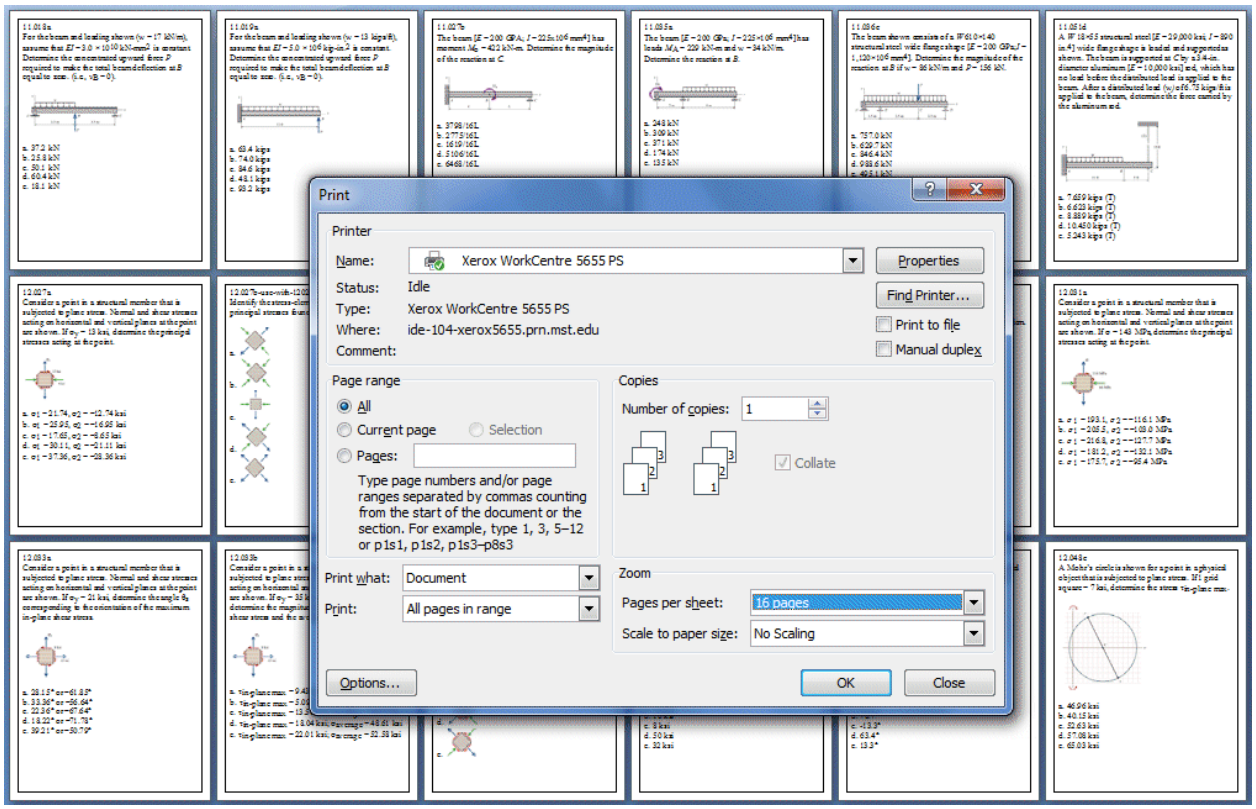


Figure 22. Optimizing the printout of all available questions.

If one wants to print an actual exam, one would select the desired questions, modify step 3 to add all of the variations instead of just one, and define Random Blocks under the Settings tab. Each question needs to be defined as a block, as shown in Figure 23. This way one variation will be randomly pulled from each block and saved to the Word file. Under Print Options, change the Randomize Questions option to Random variation *A* and select the Apply Random Blocks from the Settings option. This will allow ten variations (*A* through *J*) of the exam and their associated answer keys to be saved. Note that the letters used to define the Blocks does not correspond to the exam variations letters.

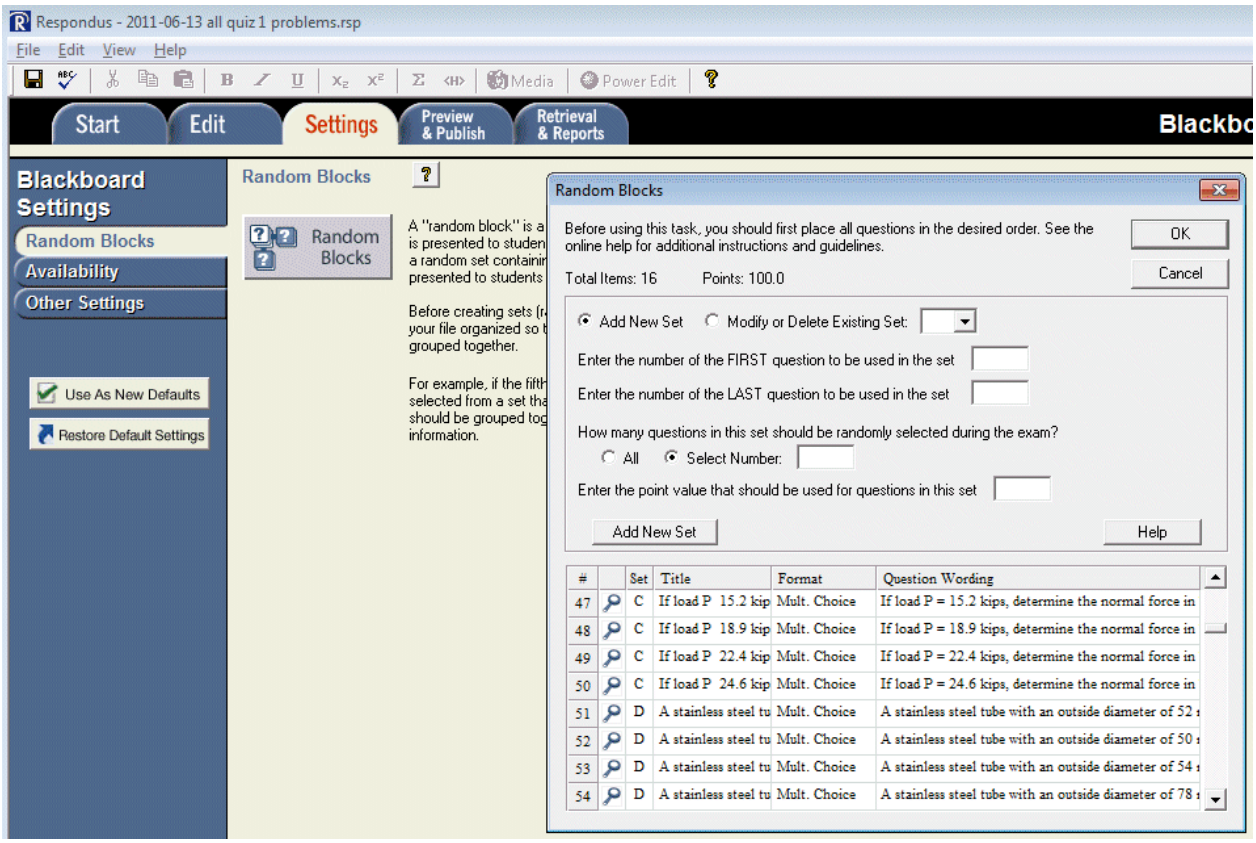


Figure 23. Specifying Random Blocks for a printed exam.

Blackboard

Blackboard is the learning management system utilized by Missouri University of Science and Technology. The narrative in this section refers to version 9. Figure 24 shows how a test T1 can be created from pools P1, P2 and P3. Each pool contains the variations of a question, and sufficiently large pools virtually guarantee no two students will receive the same exam. Figure 25 shows different ways the questions can be pulled into a test. The authors commonly pull one question from each selected pool. Figure 26 shows the Blackboard Pool Manager and some of the available pools.

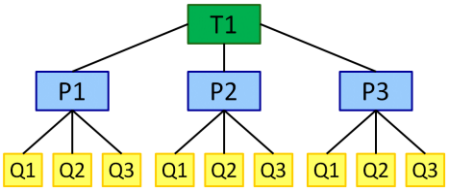


Figure 24. Blackboard Test generated from question Pools.

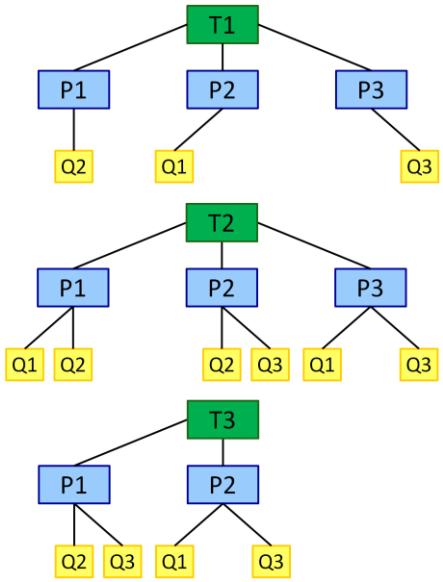


Figure 25. Alternate ways of building a test.

To create a Blackboard Test, one would follow these steps:

1. Select Tests, Surveys, and Pools in the Control Panel.
2. Select Test and then Build Test.
3. Add questions from the selected pools as Random Blocks, as shown in Figure 27.
4. Deploy the test by going to a content area, e.g. Assignments, and selecting Evaluate, Create Test, and the desired test.
5. Set the test options: test availability, feedback options (score, submitted, correct), and presentation (all at once or one at a time).

Once the test has been given, one can download the scores for each question, as shown in Figures 28 and 29. The authors typically restrict feedback immediately following the test to only the test score and later in the day upload scores for each question to Grade Center, as shown in Figure 30. Figure 31 shows how the average for each question is also made available to the students on the class web site (classes.mst.edu/ide110).

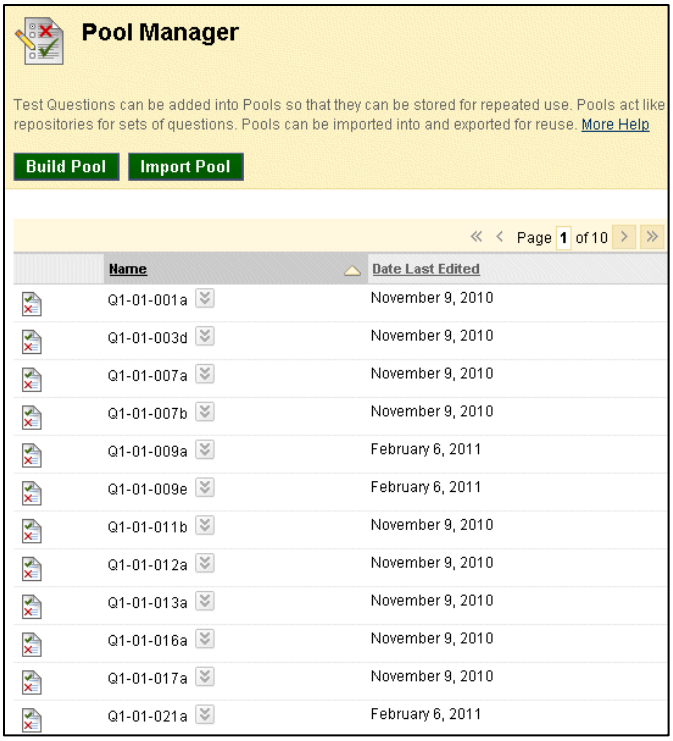


Figure 26. Blackboard Pool Manager

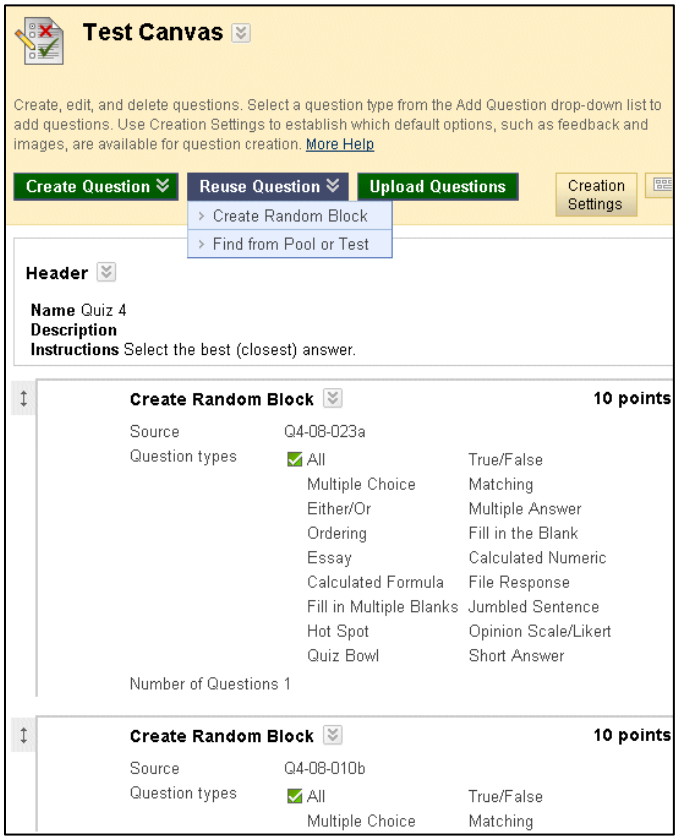


Figure 27. Blackboard Test Canvas

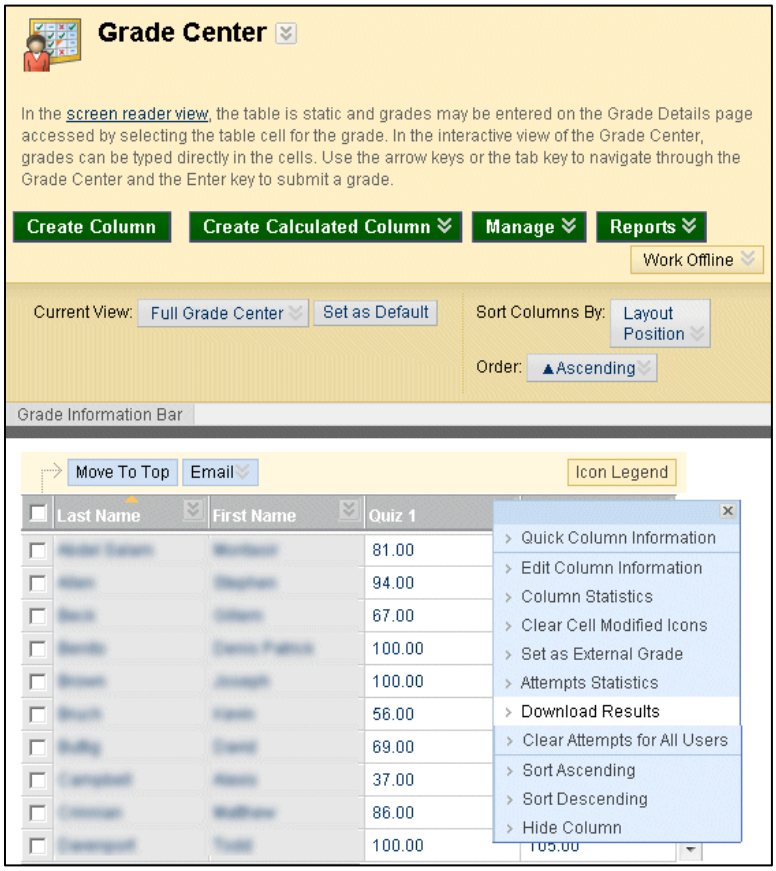


Figure 28. Downloading test data.

Username	Last Name	First Nam	Q1.01	Q1.02	Q1.03	Q1.04
			6	6	6	6
			6	0	0	0
			6	6	6	6
			6	6	6	6
			6	6	6	6
			6	0	6	6
			6	6	6	0
			6	6	6	6
			6	6	6	6
			6	0	6	6
			6	0	6	6
			6	0	6	6
			6	6	0	6

Figure 29. Spreadsheet with scores for each question.

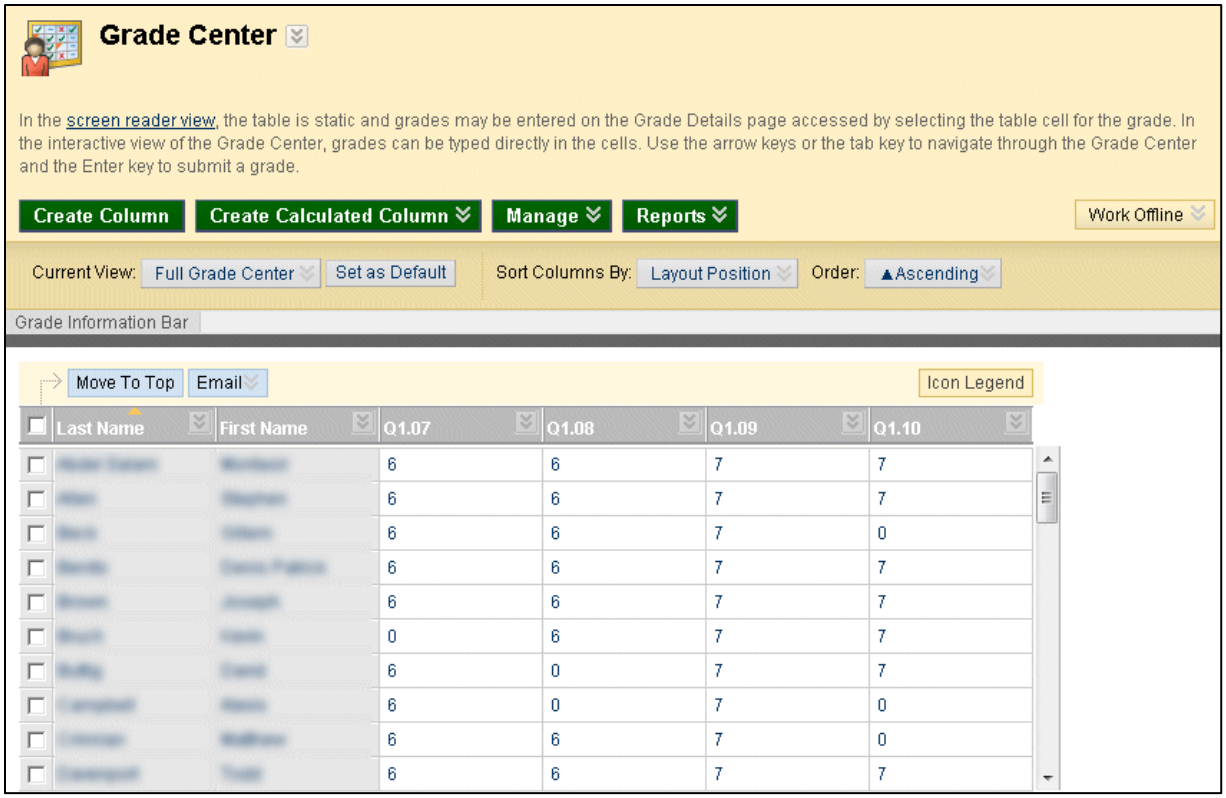


Figure 30. Scores for each question made available to students.

Problem	Topic	Sub-Topic	Performance
Quiz 1: Chapters 1-3			
Q1.01	Summation of Forces	one direction	100%
Q1.02		two directions	78%
Q1.03	Summation of Moments		96%
Q1.04	Normal Stress		86%
Q1.05	Normal Stress, Summation of Forces		100%
Q1.06	Shear Stress	bolts	90%
Q1.07		glued joint	82%
Q1.08	Bearing Stress		86%
Q1.09	Normal Strain	parallel bars	92%
Q1.10		rotating bar	76%
Q1.11	Shear Strain		65%
Q1.12			67%
Q1.13	Thermal Strain		75%
Q1.14	Young's Modulus		67%
Q1.15	Stress-Strain Curve		76%
Q1.16			67%

Figure 31. Average for each question made available on class web site.

Figure 32 summarizes how scores are processed and made available to the students for both electronic and printed exams.

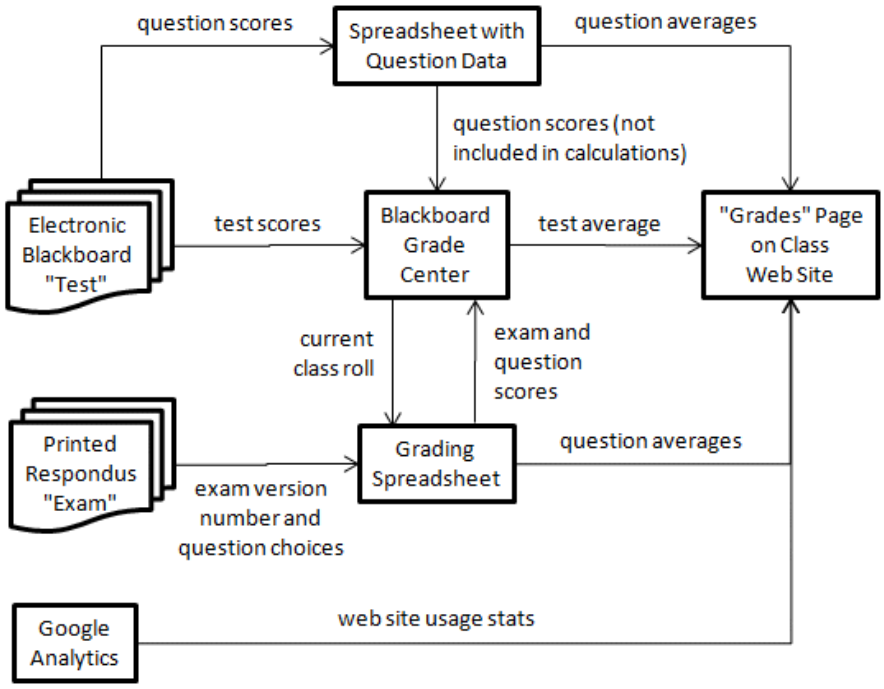


Figure 32. Data made available to students.

Results

Problems from the first edition of Dr. Timothy Philpot's mechanics of materials text were used as the inspiration for 1812 exam questions, covering 132 enabling learning objectives and 220 question categories. At present, 202 questions have been passed through Wimba Diploma, and 244 questions have been passed through Respondus to Blackboard, resulting in 2588 unique exam questions. A subset of these questions is currently being used in Blackboard Tests to evaluate the performance of 52 students during the summer semester of 2011.

Students taking the multiple choice exams in 2008 and 2009 often expressed frustration with the format. Even though the exams had been designed to provide partial credit, for each portion of what used to be a longer textbook problem, students perceived there to be no partial credit. However, frustrations seemed to lessen as the exam development process matured and students began coming into the class expecting the multiple choice format, having heard about it from friends that had previously take the course.

A straw poll prior to the fifth of eight exams during the summer of 2011 showed that the students unanimously preferred taking exams in Blackboard over a printed version, with instantaneous feedback being the most commonly voiced reason. Steve York and Tamara Knott[4] found a similar preference in 2006, even though their students experienced a variety of technical issues

while taking Blackboard exams. The authors of this paper have been pleasantly surprised to have experienced no technical issues during the summer of 2011.

A comparison of student performance in sections using open response questions to those using multiple choice questions is still ongoing, but preliminary results show no statistically significant difference on the common final exams.

Much effort went into creating the multiple choice exam questions, but creating an exam now requires about as much time as the traditional method of finding questions in a textbook and making photocopies. Grading time can now be used to analyze exam data, decide what specific topics need more focus during future semesters, and helping individual students.

Conclusions

The exam-creation process described in this paper was driven by a need to maintain high academic performance in an era of escalating class sizes and instructor workloads. The authors are happy with the progress they have made and will continue to refine the process during future semesters. They are especially satisfied with the fact that student performance data can be collected at a much finer level and that the instructor has more time to focus on the needs of individual students. The authors look forward to working with other instructors who are interested in adopting a similar process.

Acknowledgements

The authors would like to gratefully acknowledge assistance from Dr.Timothy Philpot and the Missouri University of Science and Technology Educational Technology group, eFellows Program, and Office of the Vice Provost for Academic Affairs.

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