Using Information Technology to Enhance Assessment of Learning: Automating Preparation of Course Exam Materials and Student Feedback

Ahmet Ozkul

Typo-free exams, faster and more accurate grading, and detailed written exam feedback can enhance student learning. With today's information technology it is possible to improve both the construction of tests and the quality of feedback while saving instructors' time. This paper presents a computer-based method to automate the generation of quiz questions, answer keys, and solution handouts. Using a combination of Microsoft Excel and Word, along with some programming and database management, instructors can automatically create quantitative problems in Word and answers in Excel by using random numbers with a click of a button. The system has been used successfully since 2004 in the Operations Management course at the State University of New York (SUNY) College at Oneonta. Students expressed satisfaction with the new system, and instructors found that they were allowed more time for teaching preparation and research.

Introduction

Two important components of managing college instruction are designing effective evaluations and providing meaningful feedback to students. Traditionally, teachers conduct assessments to evaluate student learning performance; however, new pedagogical approaches, such as the use of frequent small-scale assessments, have been proposed to improve the learning process (Haugen & Becker, 2005). Previously tried and tested assessment material could be one way of obtaining effective assessment. Textbook publishers may provide such material, some or all of which textbook authors may have already used in the classroom. However, this material tends to be too rigid and usually requires customization and modification by the actual instructor. He or she might change the level of difficulty, wording, or numerical values every one or two semesters. Especially in quantitative courses asking problem-type assessment questions, each modification needs to be carefully done—a moment of distraction or miscalculation may cause an error that results in an invalid question with an infeasible solution. An assessment with ill-constructed questions could undermine the overall learning process by damaging the instructor's reputation, lowering his or her confidence, and causing frustration among the students. Fairness in creating modified, challenging questions could also be a concern.

Instructors may find the post-exam review process and providing feedback to the students problematic. Explaining solution steps and correct answers may be time consuming, ineffective, and frustrating (Stark, 2006). To save class time, instructors may have to select only a few important questions, leaving the rest to the students to figure out, possibly without any extra motivational incentives. Also, due to different student learning skills, a presentation on the board or computer may not provide adequate explanatory detail.

A need for faster and more accurate grading by the instructor exists. Immediate performance feedback positively affects students, and a fast

Ahmet Ozkul is Assistant Professor, Management, Division of Economics and Business, State University of New York College at Oneonta, Oneonta, New York.

and accurate grading process should enhance student learning. Crucial to grading papers more efficiently is instructor access to a good answer key. Answer keys should be typo-free, well-constructed, and clear. They may also provide possible alternative answers to the questions.

Handling these instructional tasks can be especially challenging in quantitative courses with large enrollments and multiple sections. However, with today's information technology it is possible to improve both the construction of tests and the quality of feedback while saving instructor time.

In this paper, we present an innovative technique using information technology to automate the preparation of exam questions, answer keys, and student feedback. Our objective for this project is to enhance student learning by providing typo-free exam modifications, faster and more accurate grading, and detailed written explanations for all exam questions. We also aim to relieve the instructor from having to allocate a significant amount of time for exam and answer key preparation, having to come up with different stories and numbers for each question version, and making sure that each version is equally challenging.

We acknowledge that developing this kind of advanced system may require a lot of effort and initial time investment for an instructor. Considering the amount of benefits, though, the costs could be justified. However, these efforts may not lead directly to promotion and tenure. Hopefully, barriers in colleges that work against such instructional innovations may be overcome by new tenure and promotion guidelines that reward innovation in teaching and incentives such as financial support, professional development, and public recognition (Brill & Galloway, 2007).

In the following sections, we present a detailed description of the problem. After the problem description, we explain our method to automate the exam creation process and provide example screen shots. We conclude with the strengths and weaknesses of this technique, including actual class experience of the author who used this method for the past 3 years.

The Problem

The operations management course is an integral part of the undergraduate management curriculum in many institutions. Instructors most commonly approach this course in a way that emphasizes quantitative methods for decision making or focuses on more conceptual and strategic aspects of the discipline, usually with cases. We developed the technique presented in this paper specifically for the quantitative operations management approach, which helps students improve math, spreadsheet, and analytical thinking skills. To assess student learning, we preferred traditional exams where we could see the process the student used to solve the problem, not just the end result.

With this approach in mind, a team of faculty at SUNY Oneonta has developed an upper level, quantitative operations management course for economics and business majors. The course requires students to take a quiz and complete a homework set each week. The idea was to keep students involved with problem solving using quantitative and computer tools in small doses. However, faculty who taught operations management had to spend a considerable amount of time creating quiz and homework questions with different numerical values in multiple sets to minimize the possibility of cheating inside and outside of the classroom. Besides creating the assessment questions, instructors also had to prepare answer keys. Overall, the process required a lot of effort, considering the number of questions during the semester. For example, we created 11 quizzes with 2 quantitative problems in each, and with 3 variations; thus, we had a total of 66 questions to create every semester. Each question took about 5 to 10 minutes to prepare. With answer key preparation added in for each question, the total time required was doubled or tripled. Each version also had to be carefully constructed, typo-free, fair, and equally challenging.

The grading process was slow as well and required instructors' undivided attention so as to

avoid grading errors. Different instructors created original answer keys as needed each semester. The answer keys were not uniform; they changed significantly from problem to problem in terms of presentation and clarity. Some problems required a solution algorithm, which resulted in solution keys with different lengths depending on the complexity of the problem. In response to these issues, we decided to standardize solution keys for better readability, clarity, and accuracy.

After the exam, faculty had to review quiz questions and explain answers to the students. In a typical class, at least two of the following activities were carried out: the instructor administered a quiz, the instructor and the students reviewed quiz solutions, or the instructor and the students discussed homework solutions. The instructors then devoted the remaining class time to a fast-paced lecture. We thought student learning might be enhanced if we could allot more class time for lecture, yet provide the same or better quality quiz and homework feedback to the students by using information technology.

In brief, with the overall goal of enhancing student learning, we thought that the product of our project should ensure the following objectives:

1. Questions and answer keys would be generated using the computer, thus eliminating errors. Answer keys would be uniform, with better clarity and readability, helping to achieve accurate grading.
2. Due to straightforward, readable, carefully constructed answer keys, exam feedback could be given faster to motivate students. Faster exam generation would also help instructors allocate time for other educational tasks.
3. Many exam problem instances could be created with ease, allowing the instructor to choose the most suitable instance for the quiz.
4. A detailed solution handout would be generated and given to students right after the quiz.

Automation in Creating Quizzes and Answer Keys

The project first aimed at automating the quiz preparation process. Since past quiz questions were written in Microsoft Word and answer keys in Microsoft Excel, a natural choice for an automation tool was Microsoft Office and Visual Basic for Applications (VBA), which is the programming language for Office. A web-based system could be an alternative, but web programming is much more challenging compared to Excel's user-friendly VBA programming interface and easy numerical manipulation capability, formula writing, and charting.

We first identified the following steps for the automation:

1. Standardize each question, and create question templates in Word.
2. Standardize each answer key in Excel.
3. Randomly generate questions and the answers in Excel.
4. Store question data and solution data in Excel.
5. Transfer question data to question templates in Word.
6. Transfer solution data to solution explanation templates in Word.

One way of standardizing questions and solutions in Word is to create templates. Word allows users to create standard letter, envelope, or label templates for mass printing using a database through its mail merge function. For example, each letter can have the same exact body of text, but with a different first name, last name, and address. The same mail merge function can also be used for creating standard exam documents with changing numerical values.

The first step is to create a pool of questions for the learning assessment. One of the course objectives is to develop experience with methods, techniques, and skills in problem solving. With regular weekly quizzes, we aimed to assess this

learning objective by posing quantitative problems that tested both domain knowledge and critical thinking. Although we automated creation of the assessment instrument, we preferred not to automate the grading process by, for example, using multiple choice questions on the computer. Traditional manual grading would provide more valuable information on student problem solving and critical thinking skills. We carefully selected questions—mostly from the course textbook, *Operations Management: Processes and Value Chains,* by Krajewski, Ritzman, and Malhotra (2007)—changing some wording and customizing them to fit the needs of our students. The selection of questions from a widely used textbook assured a certain degree of validity for the assessment.

Each question had a body of text or template. While the body of the question remained the same for every instance, the numerical values differed. For example, in one question instance, we had three workstations each running 50 hours per week, while in another question instance we had four workstations each running 45 hours per week. These numbers were variables to be determined randomly in Excel, while the text remained unchanged. Using the mail merge feature, we retrieved these problem-specific values of variables from an Excel table.

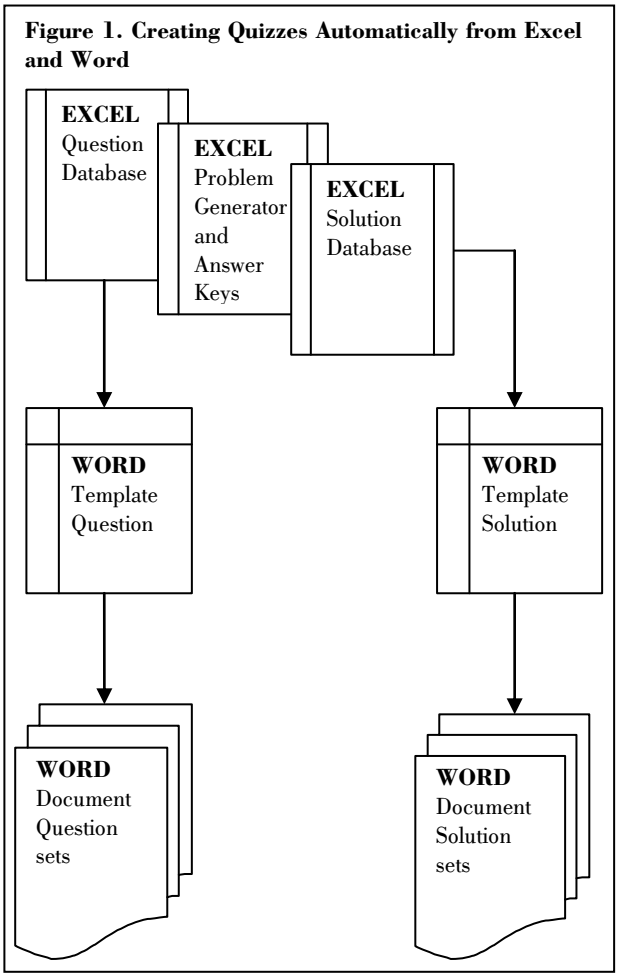
After creating a spreadsheet with formulas and supporting VBA script to solve a problem, we automatically inserted its data stored in a separate Excel sheet into the Word template, which then created a brand new question with proper wording and numbers. A VBA script, or macro, is actually an advanced version of the BASIC programming language embedded in Microsoft Office to make it more functional. A VBA script can be created by using the Record Macro function, by converting every keystroke into a small program, or by writing the code from scratch. We developed our macros by recording them first and then modifying them according to our specific needs. However, for some problems, we had to write complete programs using algorithms. Figure 1 shows the process.

How the System Works

Once problem generator and word templates have been created, instructors can begin to create questions and answer keys using random numbers. The problem generator is simply the problem's Excel solution with an associated button in which a random number generation routine resides. When the button is clicked, the VBA programming routine is activated to generate new numbers for the problem, which are then inserted back into Excel. The new inserted numbers lead to a recalculation of the cell formulas and the solution and create an answer key to the randomly created question.

This question is just one of the many possible instances of the particular problem. The instructor

Figure 1. Creating Quizzes Automatically from Excel and Word



using this system then determines which one of the problem instances and solutions generated is suitable for the actual quiz. Once a problem is deemed fair and challenging, the problem and solution data are copied into the question and solution sheets by clicking on another button, which activates a copying and pasting VBA script. This problem generation, review, and storing process continues until the system generates enough versions of the same problem.

In the operations management course, only three sets of questions are needed. Thus, three buttons are placed in the problem generator sheet. When three problem instances are generated and copied to the spreadsheets using the buttons, the user can then open the question and solution templates. Because there is an automatic link, Word looks for the Excel spreadsheets to fill the templates with data. The finished products are print-ready Word quizzes for the instructor with feedback solutions for the students. Figure 2 illustrates the problem generator and answer keys for one of the quiz questions.

EXCEL LAYOUT AND DATABASE STRUCTURE

The system is based on Microsoft Excel and Word. Two spreadsheets are created. The first sheet keeps the questions and solutions generator, and the second keeps the problem and solution data for Word to retrieve. Figure 3 shows the first spreadsheet layout in Excel. Cell values used to create the problem are located in the problem data area. As soon as the "Create the Problem" button is clicked, random numbers for the problem are generated, and the problem's solution appears in the solution area. The random numbers generated lie between minimum and maximum values defined by the user in the problem data area.

The second spreadsheet, shown in Figure 4 with example data, contains identification information, such as set, quiz, and question numbers, as well as problem variables. Since we designed the program to generate three sets, only three rows of data exist. The values in this spreadsheet are used later by Word to generate the quizzes using templates.

QUESTION AND SOLUTION DOCUMENTS

A Word template contains the body of the text for each question. In the body, the program inserts mail merge variables (V1, V2, V3, and so on) as shown in the example in Figure 5. The program automatically retrieves each variable's value from the Excel worksheet. Since there are only three records or sets of data in the spreadsheet, the template generates three instances of the same document. Each instance is a slightly different version of the same problem. Figure 6 shows an example Word document.

As stated earlier, one of the objectives of the project is to improve the learning process for

Figure 2. Problem Generator, Answer Key, and Copy Buttons

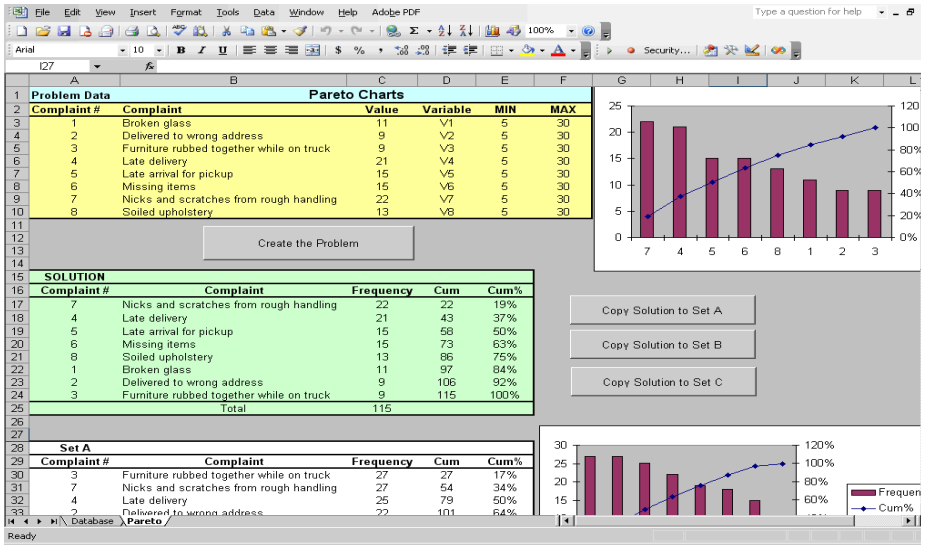


Figure 3. Excel Layout

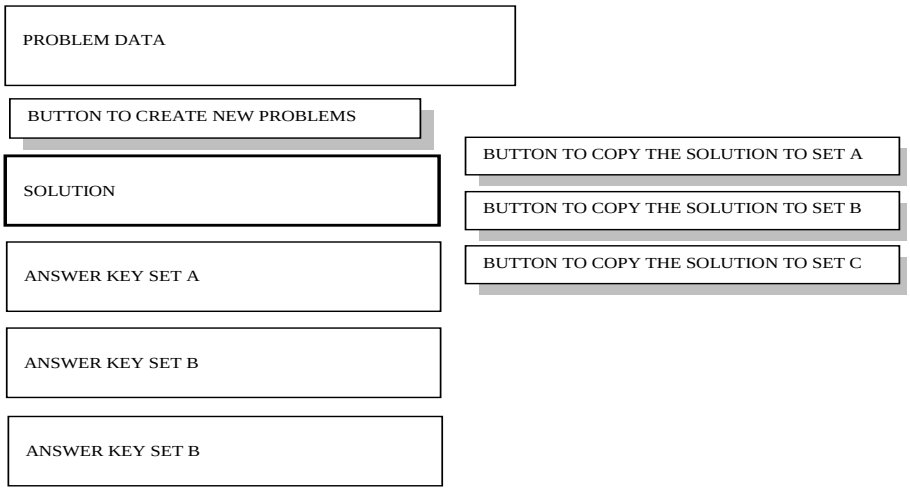


Figure 4. Database Structure

Set ID	Quiz ID	Quest ID	V1	V2	V3	V4	V5	V6
Set A	5	1	25	22	6	15	26	24
Set B	5	1	26	6	28	14	18	24
Set C	5	1	20	10	9	19	7	16

students, not just to help the instructor. We developed a solution document to provide students customized and detailed feedback about the solutions to questions. The feedback is customized because the solution works just like question templates—it gets the original question data from the Excel worksheet. Using the data from the database, the solution document explains the solution steps by using the question's original data instead of general descriptions or generic examples. Figure 7 shows the solution template.

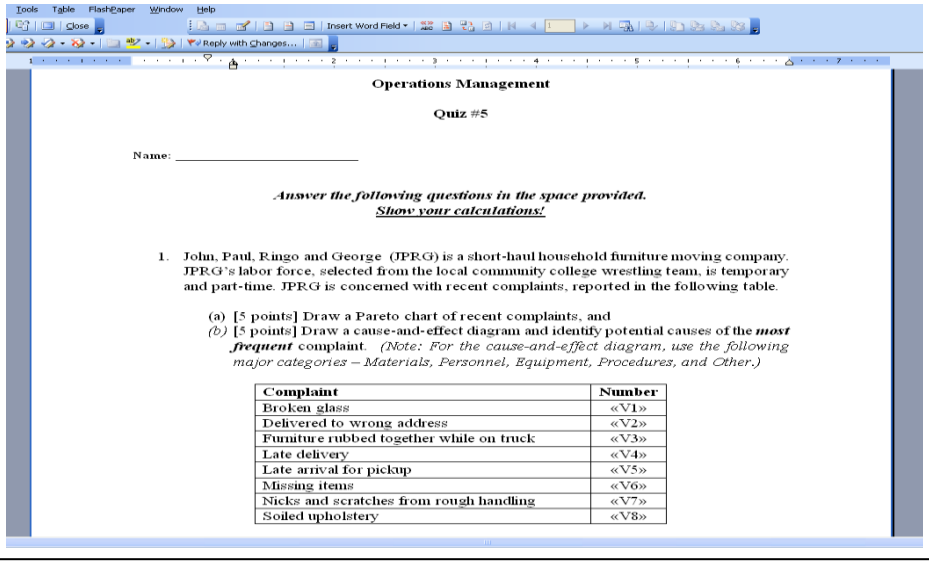
The solution documents could be quite helpful for students to see clearly the solution steps to the problems. These solutions are handed out to the students who then compare them to their own quizzes. Potential benefits include reinforcing the learning process by providing written formal explanations with actual exam data to which they can conveniently relate, helping students identify their mistakes easily, and offering reliable learning material available at any time for review before exams and even after graduation.

Also, the instructor acquires a clear, standard answer key which helps him or her in grading student papers more accurately and rapidly, as shown in Figure 8.

CONCLUSION

The automated quiz-generating system described in this paper seems promising for improving

Figure 5. Insertion of Mail Merge Variables into Body of Question Text



Operations Management

Quiz #5

Name: _____

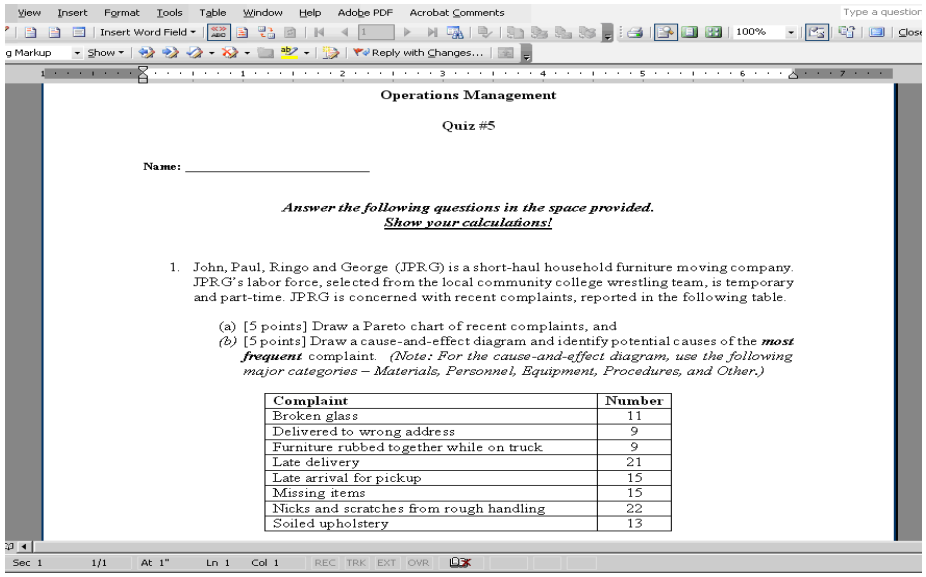
Answer the following questions in the space provided.
Show your calculations!

1. John, Paul, Ringo and George (JPRG) is a short-haul household furniture moving company. JPRG's labor force, selected from the local community college wrestling team, is temporary and part-time. JPRG is concerned with recent complaints, reported in the following table.

(a) [5 points] Draw a Pareto chart of recent complaints, and
(b) [5 points] Draw a cause-and-effect diagram and identify potential causes of the ***most frequent*** complaint. *(Note: For the cause-and-effect diagram, use the following major categories – Materials, Personnel, Equipment, Procedures, and Other.)*

Complaint	Number
Broken glass	«V1»
Delivered to wrong address	«V2»
Furniture rubbed together while on truck	«V3»
Late delivery	«V4»
Late arrival for pickup	«V5»
Missing items	«V6»
Nicks and scratches from rough handling	«V7»
Soiled upholstery	«V8»

Figure 6. Quiz Document with Numerical Data Retrieved from Excel Data Sheet



Operations Management

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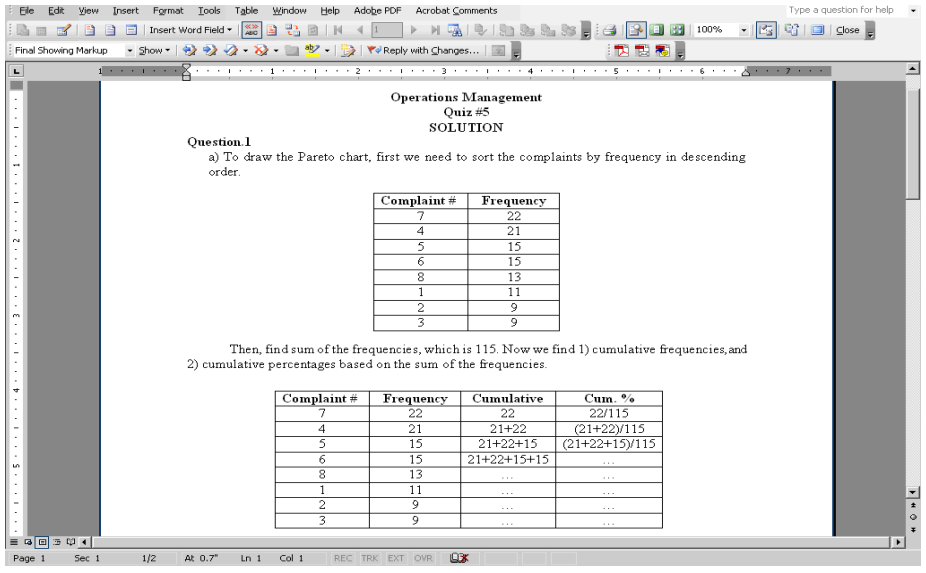
Complaint	Number
Broken glass	11
Delivered to wrong address	9
Furniture rubbed together while on truck	9
Late delivery	21
Late arrival for pickup	15
Missing items	15
Nicks and scratches from rough handling	22
Soiled upholstery	13

Figure 7. Solution Handout with Numerical Data Retrieved from Excel Sheet



Operations Management
Quiz #5
SOLUTION

Question 1

a) To draw the Pareto chart, first we need to sort the complaints by frequency in descending order.

Complaint #	Frequency
7	22
4	21
5	15
6	15
8	13
1	11
2	9
3	9

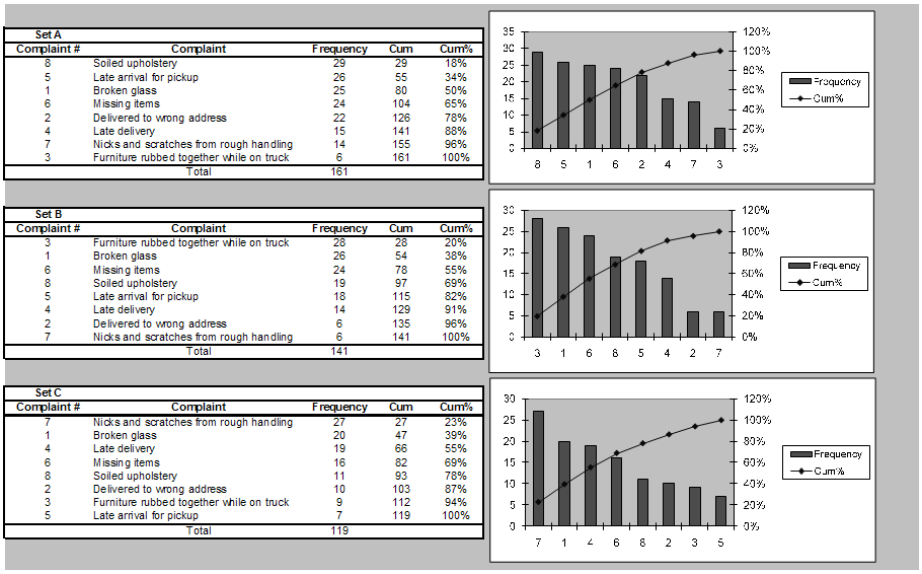
Then, find sum of the frequencies, which is 115. Now we find 1) cumulative frequencies, and 2) cumulative percentages based on the sum of the frequencies.

Complaint #	Frequency	Cumulative	Cum. %
7	22	22	22/115
4	21	21+22	(21+22)/115
5	15	21+22+15	(21+22+15)/115
6	15	21+22+15+15	…
8	13	…	…
1	11	…	…
2	9	…	…
3	9	…	…

teaching and learning in quantitative courses. Prototypes for eleven quizzes including 22 questions have been developed and actually used in the classroom since 2004. Solution printouts for each problem set described the solution step-by-step using original problem data, not generic data. This made the solutions easy to understand, relate to, and keep in mind. Such detailed solution documents provided students reference material as well, perhaps helpful during college education and after graduation. Though we did not collect any formal data, students expressed satisfaction with the prompt grading and solution handouts. Also, we completely eliminated student–instructor confrontation about errors or incorrect selection of critical values on the exam; since 2004, there has not been such an incident. As long as questions are constructed properly in the first place and random numbers are generated within reasonable limits, the system generates typo-free exams. Consistent and prompt grading may lead to additional satisfaction or motivation for students and eventually cause positive changes in behavior or performance. We have not yet measured these performance outcomes or tested the system for any performance correlations, but we plan to revise and expand it toward a more complete assessment creation and feedback system. After making these modifications, it would be especially interesting to investigate performance differences among this system, other course management systems such as Blackboard or Angel, and traditional methods.

From an instructor's point-of-view, easy problem generation at the click of a button provides great flexibility and efficiency. Out of the

Figure 8. Printable Answer Key for the Instructor



Set A

Complaint #	Complaint	Frequency	Cum	Cum%
8	Soiled upholstery	29	29	18%
5	Late arrival for pickup	26	55	34%
1	Broken glass	25	80	50%
6	Missing items	24	104	65%
2	Delivered to wrong address	22	126	78%
4	Late delivery	15	141	88%
7	Nicks and scratches from rough handling	14	155	96%
3	Furniture rubbed together while on truck	6	161	100%
	Total	161		

Set B

Complaint #	Complaint	Frequency	Cum	Cum%
3	Furniture rubbed together while on truck	28	28	20%
1	Broken glass	26	54	38%
6	Missing items	24	78	55%
8	Soiled upholstery	19	97	69%
5	Late arrival for pickup	18	115	82%
4	Late delivery	14	129	91%
2	Delivered to wrong address	6	135	96%
7	Nicks and scratches from rough handling	6	141	100%
	Total	141		

Set C

Complaint #	Complaint	Frequency	Cum	Cum%
7	Nicks and scratches from rough handling	27	27	23%
1	Broken glass	20	47	39%
4	Late delivery	19	66	55%
6	Missing items	16	82	69%
8	Soiled upholstery	11	93	78%
2	Delivered to wrong address	10	103	87%
3	Furniture rubbed together while on truck	9	112	94%
5	Late arrival for pickup	7	119	100%
	Total	119		

many problem instances generated, instructors could choose those most suitable and fair. Since we put the solution key automatically on the screen, the grading process became faster and more accurate. Since 2004, the system has saved considerable amounts of instructors' time. Using a traditional approach, it could take three instructors hours of meetings and days of discussions to prepare quiz sets for the semester that included 3 versions of a quiz with 22 questions and the associated answer keys. With the new system, instructors do not have to meet nearly as often with students about exam problems, and questions with answer keys are prepared in minutes just a few days before the quiz. Not only does this system provide relief for instructors from a once exhausting task, but instructors reported that the time and mental effort saved is now used to focus on the enhancement of teaching and research.

We think that the initial project objectives of speed, accuracy, fairness, and feedback have been satisfactorily reached by this new system. In terms of future improvements, we intend to approach creating homework sets in the same way. Question texts should be reviewed and modified over time, and new ones should be added to the collection as well. The approach described in this paper could be used by instructors of other quantitative courses, ranging from economics and engineering to statistics and mathematics. With some modifications, this system might be implemented for online courses (Gaytan, 2005).

One challenging aspect of this system that could cause instructors some difficulty is the process of creating Excel sheets and templates. Time, knowledge, and creativity are all necessary. The nature of questions must vary and require a different solution approach, ranging from simple formula writing to programming a complex algorithm. This preparation process requires that the instructors have not only a good command of domain specific knowledge, but also proficiency with Excel and Word. Some programming skills are also beneficial. Instructors might consider a team approach to using the new system, recruiting fellow instructors or even graduate students with advanced computer skills.

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