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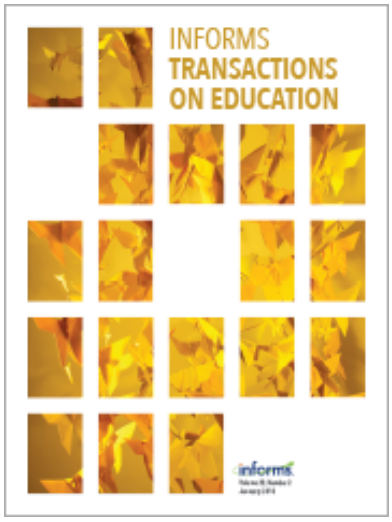

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Online Teaching in a Large, Required, Undergraduate Management Science Course

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Abstract. This paper describes how a required management science course is taught online to a large number of undergraduate business school students. The paper describes the design of the online course, how online documents are created, testing, student effort and performance, and student evaluation of the course. Some of the insights are as follows. (i) In a large, required, undergraduate business school course, many students seek a shallow rather than in-depth understanding of the course material. Doing the course online makes it easier for these students to acquire this understanding and achieve a good final course grade. (ii) The online course works well for about 85% of the students and for the university. It works less well for about 15% of the students who procrastinate, then fall behind, and cannot catch up. Improving the course design for these students is a priority. (iii) When the amount of online video material increases, students value the course more and value the instructor less. Consequently, an instructor contemplating online teaching should think very carefully about how student evaluation of instructor effectiveness will be done.

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Keywords: teaching management science • online teaching

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1. Introduction and Literature Review

There have been many innovations in how we teach management science to undergraduate business school students. In the 1990s, the use of spreadsheets for data management and problem formulation and solution increased dramatically (Erickson and Turban 1985, Jones 1986, Winston 1996, Conway and Ragsdale 1997, Martin 2000). The next innovation focused spreadsheet capabilities on business decision models and the use of management science in these models (Bodily 1996, Mather 1999, Powell 2000, Robinson et al. 2003, Sokol 2005, Grossman 2006). Leong and Cheong (2008), for example, suggested that a separate course in business modeling be taken before the course in management science. A more recent innovation was the use of online video tutorials to show the use of management science tools in business models (Winch and Cahn 2015, Sharkey and Nurre 2016). How these and other innovations (e.g., Grossman et al. 2016) were implemented depended on whether the students were from the business school or from engineering, whether they were undergraduate or graduate, whether the course was required or elective, and the class size.

Having participated in several of these innovations, we now report in this paper our experience with another innovation: teaching online an entire required management science course to a large number (about 500) of undergraduate business school students. The literature on this innovation is small. An important paper is by Scherrer (2011). She reports on online teaching a required undergraduate business school statistics course. Despite differences in the subject (statistics versus management science) and the class size (about 40 students versus about 500 students), there are similarities between her experience and our experience. Sharkey and Nurre (2016) wrote another important paper. They report on using online video tutorials in a required undergraduate management science course in industrial engineering. Despite differences (the students are undergraduate engineering, only some material is online, and the online material is supplementary), there are also similarities. We will compare our experiences with their experience. The experiences and practices described in this paper are ones that are working well in a large undergraduate business school required management science course. They are not necessarily best practices for every online course.

This paper is organized as follows. Section 2 and Appendices A and B describe the online management science course. Sections 3 and 4 discuss how online material was created and the challenge posed by

Figure 1. Topics in the Required Undergraduate Business School Management Science Course

	Lecture hours	On-line notes and documents	Podcast hours
Lecture topics			
Introduction	1	yes	1
Excel review	1	yes	0
Simple business decision models	2	yes	3
Linear programming			
graphical	3	yes	3
excel solver	1	yes	1
standard problems	3	yes	4
sensitivity analysis	4	yes	4
integer lp	1	yes	1
Decision analysis			
payoff tables	3	yes	3
decision trees and treeplan	4	yes	4
utility functions	3	yes	3
Simulation			
manual	2	yes	3
excel	4	yes	4
simquick	2	yes	2
Waiting line models	4	yes	4
Other topics			
Software	0	yes	1
Quizzes	0	yes	1
Exams	0	yes	2
Total	38		44

different computers and software. Section 5 describes the difficult issue of testing students. Section 6 reports on student effort and performance in the course and student evaluation of the course. Conclusions follow in Section 7.

2. Course Organization

A few years ago, the management science area in the business school decided to update the required undergraduate business school course in management science by further increasing the use of Excel and moving elements of the course online. Increasing the use of Excel would make the course more relevant and interesting for undergraduate business school students. Moving elements of the course online would make taking the course more convenient for students and might enable the department to use fewer resources to run the course (e.g., the instructor could receive less credit for teaching the course; teaching assistance could be reduced; the number and size of rooms for lectures, quizzes, and examinations could be reduced; and enrolment could be increased). Enrolment was 400 students, would soon increase to 600, and reach 800 by 2019.

Three years later, the entire course was online. Figure 1 shows the organization of the January 2017 course. The topics covered are Excel review, business modeling, linear programming (LP), decision analysis, simulation, and waiting line models (Appendix A gives detailed descriptions). There are three 50-minute lectures per week for 13 weeks plus a final examination. Except for the final examination, the course can be done entirely online. The final examination is a traditional examination done on campus.

Figure 2 shows a portion of the course schedule. For example, the Excel review and business modeling topics are covered in lectures and podcasts 2–4 on January 6, 9, and 11. There is a 16-page lecture notes document and an Excel review document (both online), readings from the required textbook (Balakrishnan et al. 2013), and assigned practice problems that students do on their own and check against solutions posted online.

Most students attend the first lecture (January 4) when the course outline is presented. After that, they have several possibilities for completing the course. They can attend traditional lectures, do the course entirely online, do a combination of traditional lectures and online work, or follow some other strategy, such as using only the textbook or working with a friend or tutor. Students are not required to declare their choice; they follow whatever possibility they like and change it whenever they like. The lecture rooms are sufficiently large that students are always able to find a seat whenever they decide to attend a lecture. About 20% of the students regularly attended the lectures. About 65% of the students did the course entirely online; they never attended a traditional lecture. About 15% did not attend the lectures and did not do the course online;

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Figure 2. Course Schedule in the Required Undergraduate Management Science Course

Commerce 3QA3 Course Schedule - January 2017

Topic	Lecture/podcast number	Day	Date	Lecture Notes pages	Textbook pages	Practice problems
	1	Wed	Jan 4	Course outline, Ch 1 Notes		Ch. 1: Disc. quest. 2,12; Prob. 22,23,24, solve all these problems using Exc Bill Pritchett Practice Problem on p. 16 of Lecture Notes, solve using Excel
Excel review, Business models	2	Fri	Jan 6	Ch 1 Notes pp. 1-16; Excel review workbook	Ch 1, all pages; Excel review	Additional business decision model - product mix - p. 16 in Lecture Notes
	3	Mon	Jan 9			
	4	Wed	Jan 11			
LP model, graphical solution, computer solution	5	Fri	Jan 13	Ch 2 Notes pp. 1-3	Ch 2, pp. 19-40	Ch. 2: Disc. quest. 3,4,7; Prob. 13,17 (graphical solution only)
	Quiz 1: Sun. Jan. 15, 12 noon to Mon. Jan. 16, 12 noon					
	6	Mon	Jan 16	Ch 2 Notes pp. 4-9	Ch 2, pp. 41-56	Ch. 2: Disc. quest. 10,11,12; Prob. 13,17,27,29,43; Solve these problems u
	7	Wed	Jan 18	Ch 2 Notes pp. 10-13		
	8a	Fri	Jan 20	Ch 2 Notes pp. 13-15		
Standard LP problems	8b	Fri	Jan 20	Ch 3,5 Notes pp. 1-2	Ch 3, pp. 65,66,77-81	Ch. 3: Prob. 3,13; Solve these problems using Solver in Excel
	Quiz 2: Sun. Jan. 22, 12 noon to Mon. Jan. 23, 12 noon					
	9	Mon/Tue	Jan 23/24	Ch 3,5 Notes pp. 2-5	Ch 3, pp. 63-77,81-104 Ch 5, pp. 165-168	Ch. 3: Prob. 7,9,12,17,21; Ch. 5: Prob. 17; Solve these problems using So
	10	Wed	Jan 25	Ch 3,5 Notes pp. 6-9		
	11	Fri	Jan 27	Ch 3,5 Notes pp. 10-18		

most of them did a mix of occasional lectures, occasional podcasts, working with friends, etc. Most students in the 15% group did not do well in the course; they procrastinated, fell behind, and could not catch up. We will examine this carefully in Section 6.

"Avenue to Learn" is the name of the online learning management system that the university uses (Appendix B). This is where all the course documents were posted, the online quizzes and online examinations were taken, assignment submissions were collected, online discussions were held, and grades were posted. Figure 3 is instructor information from the Avenue to Learn site for the course. It gives data on how students used the course documents. All documents can be used online; they can also be downloaded, saved, and used offline. There were 493 students in the January 2017 course. There were 128 students in another term (the course was taught the same way in that term); therefore, the total enrolment in the academic year was 621 students.

Figure 3 reports that all 493 students used some of the online documents. On average, a student spent 26 hours and 48 minutes online using this content. This is a good value, because it indicates that students spent a lot of time with the documents, especially when we add the much larger amount of time that students would have worked offline with the documents.

The first document in Figure 3 is a pdf file of the final course outline; 477 students viewed this document. There was an earlier preliminary course outline document. No usage statistics are available for the preliminary outline, because that information was lost when the document was deleted and replaced by the final course outline. It is likely that most of the other 493 − 477 = 16 students used the preliminary course outline document. The second document in Figure 3 is an Excel file of the course schedule that we saw in Figure 2. The usage is lower for this document (254 students), likely because this schedule is also included in the course outline. The third document is a video podcast of the course outline. Notice that this podcast is 50 minutes long, but students only spent an average of about 10 minutes viewing it. This is likely because (i) students downloaded the podcast and used it offline, (ii) students moved around in the podcast to find something specific that they were looking for (e.g., information about an examination), or (iii) it was more convenient for students to download and read the pdf file of the course outline.

The next section in Figure 3 shows the documents and usage statistics for the topic in Lectures 8b–11. This topic is "standard LP problems." The first document is a pdf file of the (revised) lecture notes; 399 students used this document. This is 81% of the class. It was common for the instructor to revise lecture notes and other course documents during the course as small errors were discovered or issues emerged where students needed more clarification. When a revised document was uploaded, the earlier document was deleted along with its usage data. Therefore, the total number of students who used a lecture notes document for this topic is higher than 399. The next document in Figure 3 is the Excel workbook for these lecture notes; 354 students used this document. The low average time spent on this document is an indication that students downloaded and used the Excel workbook offline.

It is interesting that 399 students used the lecture notes document but that only 354 used the Excel workbook. This suggests that 399 − 354 = 45 students read about the topic in the lecture notes but did not practice the topic in the Excel workbook. This pattern of "reading but not practicing" was common in the course. One explanation is that, in a required undergraduate business school course, many students want a "shallow" rather than "in-depth" understanding of the course topics. (In an elective course, these students are more

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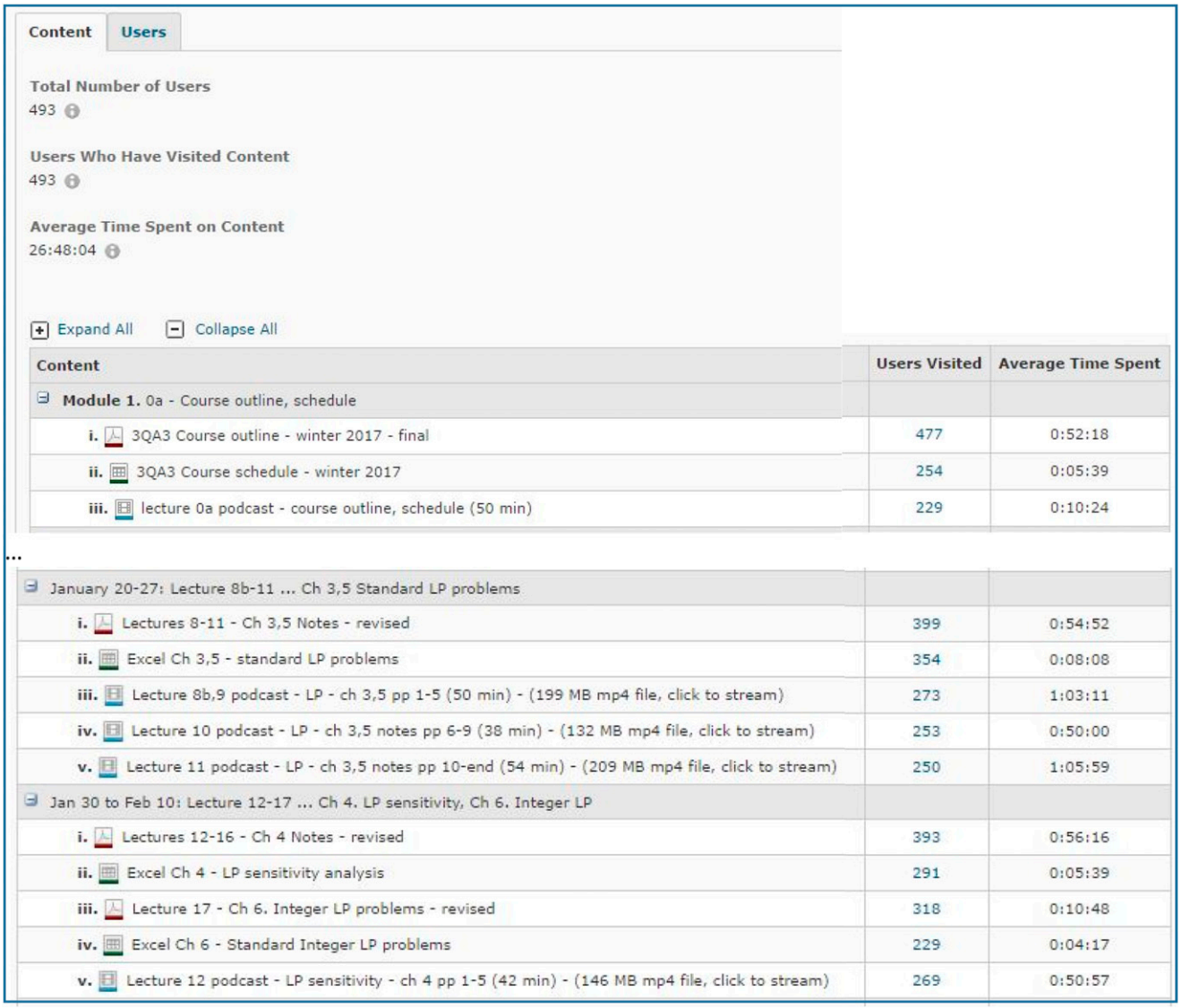
Figure 3. Documents Used in the Required Undergraduate Management Science Course



Content | Users

Total Number of Users
493

Users Who Have Visited Content
493

Average Time Spent on Content
26:48:04

Expand All | Collapse All

Content	Users Visited	Average Time Spent
Module 1. 0a - Course outline, schedule		
i. 3QA3 Course outline - winter 2017 - final	477	0:52:18
ii. 3QA3 Course schedule - winter 2017	254	0:05:39
iii. lecture 0a podcast - course outline, schedule (50 min)	229	0:10:24
...		
January 20-27: Lecture 8b-11 ... Ch 3,5 Standard LP problems		
i. Lectures 8-11 - Ch 3,5 Notes - revised	399	0:54:52
ii. Excel Ch 3,5 - standard LP problems	354	0:08:08
iii. Lecture 8b,9 podcast - LP - ch 3,5 pp 1-5 (50 min) - (199 MB mp4 file, click to stream)	273	1:03:11
iv. Lecture 10 podcast - LP - ch 3,5 notes pp 6-9 (38 min) - (132 MB mp4 file, click to stream)	253	0:50:00
v. Lecture 11 podcast - LP - ch 3,5 notes pp 10-end (54 min) - (209 MB mp4 file, click to stream)	250	1:05:59
Jan 30 to Feb 10: Lecture 12-17 ... Ch 4. LP sensitivity, Ch 6. Integer LP		
i. Lectures 12-16 - Ch 4 Notes - revised	393	0:56:16
ii. Excel Ch 4 - LP sensitivity analysis	291	0:05:39
iii. Lecture 17 - Ch 6. Integer LP problems - revised	318	0:10:48
iv. Excel Ch 6 - Standard Integer LP problems	229	0:04:17
v. Lecture 12 podcast - LP sensitivity - ch 4 pp 1-5 (42 min) - (146 MB mp4 file, click to stream)	269	0:50:57

likely to want an in-depth understanding.) Reading only the lecture notes gives this desired shallow understanding. Furthermore, in most of the required undergraduate business school courses, carefully reading and studying only the lecture notes are usually sufficient to achieve a good final course grade. We will examine this in Section 6.

The next three documents in Figure 3 are the video podcasts for Lectures 8b–11. The total length of these podcasts is 50 + 38 + 54 = 142 minutes. The number of students using these podcasts ranges from 250 to 273, and the average time spent on these documents ranges from 50 to 66 minutes. On average, 53% of the students spent 179 minutes online with the three podcasts. Recall that 65% of the students are doing the course entirely online; 53% is less than this, which indicates that (i) some students used earlier versions of the podcasts and (ii) some students worked with friends in groups. The average time spent with the podcasts is good considering that many students download the podcasts and use them offline.

The pattern of usage statistics just discussed is typical for all of the topics in the course. For example, the last part of Figure 3 shows data for the next topic in Lectures 12–17; 393 students or 80% of the students used the (revised) lecture notes. Fewer (291 ÷ 493 = 59%) used the accompanying Excel workbook—an indication that many students read but do not practice; 269 students or 55% of the students used the first video podcast.

As mentioned earlier, about 20% of the students (493 × 20% = 99 students) regularly attended the lectures. The rest (493 – 99 = 394 students) should be using the podcasts. However, for example, only 269 students

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used the podcast for Lecture 12. If all of these students came from 394, then 394 − 269 = 125 students did not attend Lecture 12 or use the podcast. About one-third of these students worked with friends; therefore, for approximately 125 × (1 − 1/3) = 83 students or 15% of the class, learning can come only from reading the lecture notes. (Learning could come from the textbook, but it seems unlikely that students who do not attend lectures or use podcasts will instead purchase and read a textbook.) This analysis suggests that lecture notes are the most important learning material in the course. Consequently, very detailed and helpful lecture notes were a top priority in the course. This is why lecture notes were revised whenever it was possible to make them more useful for students.

The 15% of students just discussed are a "hard-to-reach" group of students for the instructor. They do not attend lectures or use podcasts, and they likely do not read the textbook or work through the practice problems. Many of them do not do well in the course. Scherrer (2011) reports a similar experience; in her business school statistics course, the number of these students is about 16% of the class. She cites other research reporting the same experience: for example, "McLaren (2004) compares persistence and performance of online versus traditional students in... [her] business statistics course... She found strong evidence that more online students failed to persist by either officially withdrawing or by 'vanishing,' but there was no evidence of a difference in performance among those who did persist in the course" (Scherrer 2011). We will examine this more carefully in Section 6.

Notice at the top of Figure 3 that there is a tab called Users. Opening this tab gives detailed data on the documents that each student used. This information is helpful when students complain about difficulties and grades and at the end of the course when the instructor reviews students who failed the course. These data indicate the topics where a student used or did not use documents (e.g., did a student use a particular Excel workbook or view a particular podcast), and therefore, they are an indication of the topics where the student may not have studied the material.

3. Creating and Editing Video Files for the Podcasts

We used many different software packages to create video files of the lectures and other items, such as instructions for installing and using software and taking quizzes and examinations (Figure 1). We also used many software compression schemes to compress large, high-quality video files into smaller video podcasts. The learning management system at our university initially restricted podcast sizes to no more than 50 Mb to not overload the learning management system's (limited) streaming capacity. Unfortunately, the video quality in files of this small size was very poor. When we compressed our video files to this small size, students complained that they could not clearly see the text, the contents of cells in the Excel worksheet, and other items in the video. This video quality seemed to be satisfactory for video files in other business school courses (e.g., marketing or human resources) or courses in other disciplines (e.g., history or psychology), where for example, PowerPoint was used and the material was primarily large text. However, the video resolution was too fuzzy for the detailed material in the management science notes and Excel worksheets. In addition, students expected video quality comparable with what was common on the internet (e.g., YouTube). To give students podcasts that were useful and comparable with what they were accustomed to, we needed file sizes of at least 600 Mb for a 50-minute lecture. Unfortunately, this was too large for the university's learning management system. We could have posted these large files on YouTube but chose not to. Doing this would separate the video files from the lecture notes and Excel workbooks in the learning management system and make it more cumbersome for the instructor to revise the podcasts. After about two years of experimentation, we were finally able to create high-quality video files of about 1 Gb for a 50-minute lecture and then compress these files to about 200 Mb in mp4 format for video streaming (Figure 4). The university's learning management system then allowed us to post these (larger) video file sizes. The quality was satisfactory for the students, and the files streamed well, even during busy time periods. At the end of the course, students had three complaints about the files. They wanted even higher resolution to make it easier to see details in the Excel worksheets, more precise audio, and more streaming functionality, in particular better controls for playback speed and indexing to move through topics in the video. The streaming functionality in the learning management system was surprisingly limited.

The video recording software that we now use is better than everything else we tried. It is not expensive (about $200), and it is reasonably easy to use. It is very reliable, meaning that it never crashes, which is unusual compared with other software. The compression scheme reported in Figure 4 is the maximum compression possible. Compressing more than this renders the resolution unacceptable; students would not be able to follow the cursor as it moves around the screen (we highlight the cursor using PenAttention version 10), and they would not be able to see the contents of Excel cells (e.g., formulas, format, data table, chart, and statistics). We hope that the university upgrades its video streaming capability. When it does, we will change our compression scheme to produce and post higher-quality podcasts.

Figure 4. Video Production and Compression

Video recording:
software: TechSmith Camtasia version 9.0.1 (November 2016)
record/edit dimensions: 1920 x 1080

Compression:
format: mp4; frame rate: 15 fps; key frame rate: 5 seconds; video quality: 50 %; bitrate: 800; audio bitrate: 64 kbps

File sizes:

Document	Video file size	Compressed video file (i.e. podcast) size
50 minute lecture (e.g. Lecture 8b,9 in Figure 3)	1.08 Gb	199 Mb
38 minute lecture (e.g. Lecture 10 in Figure 3)	0.89 Gb	132 Mb
54 minute lecture (e.g. Lecture 11 in Figure 3)	1.15 Gb	209 Mb

4. Computer Types and Excel Versions

Instructors, students, the textbook, and computers in the university libraries and laboratories use any of five possible combinations of computer types and Excel versions: Windows (PC) computer with Excel 2010, 2013, or 2016 or Macintosh (Mac) computer with Excel 2011 or 2016. The students are split almost evenly between four of these: PC with Excel 2013, PC with Excel 2016, Mac with Excel 2011, and Mac with Excel 2016. This means that the instructor and teaching assistants must be comfortable with all of these combinations. It takes a long time to become knowledgeable about all of the issues that arise because of differences between these combinations. For the instructor, the issues may seem small, but for undergraduate business school students, they are large and if not resolved quickly, become major impediments to learning. It is best for the instructor and the teaching assistants to use both computer types and be comfortable with all versions of Excel. Happily, the differences between the two most recent combinations, PC with Excel 2016 and Mac with Excel 2016, are fewer than the differences between earlier combinations. Therefore, issues associated with differences should diminish in the future.

In a very large class, it is likely not possible to require all students to use the same computer (e.g., PC) or the same Excel version (e.g., 2016). Rather, it is likely better if students see that management science and Excel can be used easily on many different systems. It is quite satisfying to see undergraduate business school students gain confidence as they develop Excel skills and management science expertise on their own computers. This may be an aspect of what Grossman et al. (2016) call self-efficacy. We also strongly encourage students to use two computer monitors (when they work at home). One monitor will be their normal computer screen (usually a laptop); the other will be an external monitor configured as an extended monitor. Students can then display their notes, a podcast, or a practice problem on one monitor, while on the other monitor, they run Excel, create and format their worksheet, generate a solution, do sensitivity analysis, etc. This is too much information for just one monitor. In addition, two monitors are helpful when students do the online quizzes and examinations.

5. Testing Students

There are five online quizzes, two online examinations, and one traditional final examination. This is approximately one quiz or examination every two weeks. This high frequency of testing is necessary to force students to keep up. Most students who fall behind do not catch up and then do poorly in the course.

Several things are done to reduce the amount of cheating on the online quizzes and examinations. First, the quizzes and examinations are time limited and are composed of randomly selected, randomly ordered questions from a large question bank. Second, we use a testing feature in the learning management system called "cannot go back" that works as follows. Only one question at a time appears on a student's computer screen. The student must answer that question; she cannot go to the next question until it is answered. When she goes to the next question, the previous question disappears and the student cannot go back to it. Therefore, the student sees each question only once. If the student waits at a particular question until another student texts a screenshot of the same question or a similar question, then the student may have to wait for quite a while. The student then loses time and has to rush to finish the quiz or examination. The student cannot skip a question and return to it later when she receives a relevant screenshot from another student. At the beginning of the course, students are nervous about this cannot go back feature, but after they experience it in the early quizzes, the nervousness diminishes.

Because the main purpose of the quizzes is to help students keep up with the material and prepare for the examinations, the grading on the quizzes is easy. Each quiz consists of (approximately) 14 questions, but only (approximately) 10 questions need to be answered correctly to receive full marks. Therefore, 10 or more correct answers earn a mark of 10 of 10 or 100%; 9 correct answers earn a mark of 9 of 10 or 90% and so on. This reduces the amount of cheating, because there is less reason to cheat when you can make mistakes and

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still achieve a good mark. This easy grading scheme; the students' ability to consult their notes, textbook, etc.; and the comfort of working on their own computer at home or some other quiet place make the online quizzes successful. An average of 80% of the students write each quiz, and the average mark is 9.5 of 10. Unfortunately, about 20% of the students do not write each quiz; the marks for these students (usually two marks per quiz) are added to the marks for their final examination. More information on this is in Section 6.

The two online examinations are also composed of randomly selected, randomly ordered questions from a large question bank. Each examination has about 50 questions and is 2.5 hours long. All questions are multiple choice and worth one mark each (like the quiz questions). Questions are grouped so that students can prepare one Excel worksheet and answer several random questions based on that worksheet. There are two "large, difficult" problems worth about 25% of the total mark. One problem is at the beginning of the examination, and the other is at the end. Students must model each large, difficult problem; prepare an Excel worksheet; and answer several random questions based on the worksheet. They must drop their worksheet in a drop box, where teaching assistants later retrieve and grade it. Each large, difficult problem is graded out of 10 marks. Six marks are for the worksheet in the drop box. Marks are awarded for format, neatness, layout, borders, color, etc. The other four marks are for the random questions. The grading is tough to emphasize the principle that students need good Excel skills to do well in the course. The grading is manageable for the teaching assistants, because the random questions are graded automatically, and the teaching assistants only have to grade the worksheets. The first large, difficult problem at the beginning of the examination forces students to start on time, because the students must drop their worksheet in a drop box that closes 45 minutes after the examination begins. Students then work quickly through the other questions on the examination to have enough time at the end of the examination to do the second large, difficult problem. Like the quizzes, students cannot go back to any previous question. We are always pleasantly surprised at how well students do on the two large, difficult problems. It is clear from the worksheets in the drop box that students are developing Excel skills and learning management science.

The best way for a student to cheat on an online quiz or examination is to have a student who took the course in a previous year help them during the quiz or examination. Unfortunately, we do not know how to prevent this. This issue is the reason that the final examination is not online. The final examination is a traditional, written, two-hour long examination covering all of the material in the course. There are approximately 60 multiple choice questions. The examination is scheduled and invigilated by the university. Students can prepare and use one page of formulas and notes. The examination is worth as much as possible (currently 35% of the course mark). As we will see in Section 6, it is a very difficult examination. Students who cheated on the online quizzes and examinations and did not learn the course material will do poorly on the final examination and will end up with a low mark in the course. The five quizzes and two online examinations are worth enough that a cheater may be able to pass the course (50% or more is needed to pass) but are not enough that a cheater will end up with a good mark in the course.

The five online quizzes and two online examinations are difficult to create and maintain, because they require a very large number of questions and multiple choice answers. Students take screenshots of everything, and therefore, questions and answers must be constantly revised. A textbook test bank is insufficient; the work of creating and maintaining questions and answers must be done by the instructor. If the instructor cannot do this, then the online testing will not work.

6. Student Effort and Performance

6.1. How Students Use Documents

One hundred twelve documents are online. With respect to file type, 28 documents are text files (i.e., pdf), 40 documents are Excel files, and 44 documents are video files (i.e., mp4). Figure 5 describes the contents of the files. Five documents contain course information (i.e., the course outline and schedule, instructions for loading and using software, and instructions for doing quizzes and examinations). Thirteen documents are lecture notes (one document per week for 13 weeks); 44 documents are podcasts (i.e., mp4 video files for the 38 lectures plus videos on software, quizzes, and examinations). Fifty documents contain practice material (i.e., Excel files to accompany the lecture notes and practice problem answers and worksheets).

Figure 5 also shows the number of students who used each document. For example, an average of 415 students used (i.e., downloaded) each of the five course information documents (e.g., the course outline). The standard deviation is 92, which means that some course information documents were used more than others (e.g., 477 students used the course outline document) (Figure 3). The data in Figure 5 understate the actual usage, because as mentioned earlier, documents were edited and revised during the course, and when a revised document was posted, the earlier document was deleted along with the record of the students who used it. During the course, all of the course information, lecture notes, and podcasts documents were revised at least once. Several insights can be gleaned from this usage data.

Figure 5. Analysis of Course Documents

Document type	Number of documents	Number of student 'visits' per document	
		Mean	Standard deviation
Course information i.e. outline, instructions for software, quizzes, exam	5	415	92
Lecture notes	13	378	41
Podcasts	44	238	55
Practice material e.g. Excel files for lectures, practice problems	50	169	111
Total	112		

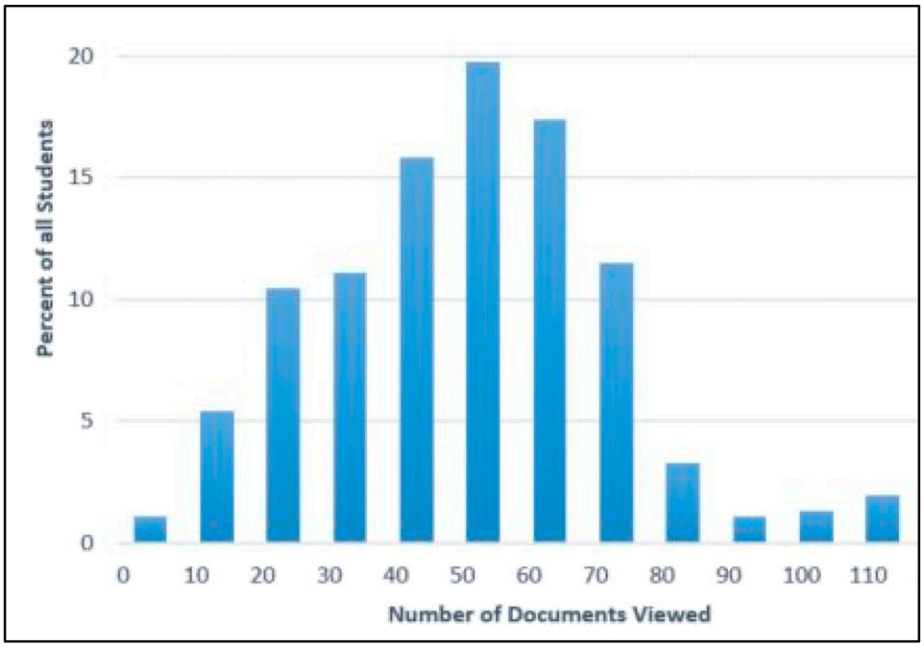
6.1.1. Insight 1. One hundred twelve is a large number of documents for students to use and manage. Figure 6 shows the frequency distribution of the number of documents that each student used. The mean number of documents that a student used is 52, and the standard deviation is 22 documents. Again, the mean is a low estimate, because it does not include earlier versions of documents that students may have used. This large number of documents is the main reason that the 38 lecture podcasts (each about 50 minutes long) were not split into a larger number of shorter podcasts (e.g., $3 \times 38 = 114$ podcasts of about 20 minutes each). Although 20 minutes is considered a better length for a podcast, the students were comfortable with the 50-minute podcasts. Each podcast corresponded to a lecture, which made it easy for students to schedule and manage their work. We are, however, experimenting with shorter podcasts and will use some in the next offering of the course.

6.1.2. Insight 2. The documents used most were the 5 course information documents and the 13 lecture notes documents. Almost all students used (i.e., downloaded) these documents. This confirms that the lecture notes are the most important documents in the course. Every effort was made to make them as error-free and useful as possible.

6.1.3. Insight 3. With respect to the podcasts, an average of 238 students viewed each podcast. This may seem low but recall that (i) some students viewed earlier versions of the podcast, (ii) some students worked with friends in groups, (iii) about 20% of the class regularly attended lectures and did not use many podcasts, and (iv) about 15% of the class did not regularly attend lectures or regularly use podcasts.

6.1.4. Insight 4. Most surprising was the low number of students who used the practice material documents.

Figure 6. Student Usage of Course Documents



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These are Excel files for the examples in the lectures, practice problems helpful for practicing and learning the course material, and practice and review problems helpful for the quizzes and examinations. On average, 169 students used each document. The standard deviation was very high, which means that some documents were used a lot more than others (e.g., 353 students used the first practice problems solutions document, but only 53 students used the last practice problems solutions document). This suggests that (i) most students want a shallow rather than an in-depth understanding of the course material and that (ii) students can achieve a good final course grade without working through a lot of practice material.

6.2. Online Discussion

Occasions for discussion were the online discussion board, weekly office hours (eight hours with teaching assistants and four hours with the instructor), and emails or texts. The total amount of discussion was not large. We believe that this was because the course documents were very clear and complete. The total number of emails or texts was about 800. These were answered quickly. Office hours were not excessively busy. On the discussion board, there was a total of 5,002 views of 42 threads made up of 80 posts authored by 24 students and the instructor. Each thread was viewed an average of $5{,}002 \div 42 = 119$ times. All threads were a simple question followed up by an answer from another student or the instructor. Examples of questions are: "Why is Excel Solver saying 'The objective cell values do not converge'?," "Can anyone explain the meaning of the third constraint in practice problem 17?," and "How do you add the red lines on a decision tree in TreePlan?." Several times, a question prompted a revision of a course document (e.g., a lecture note or a practice problem solution). This use of online discussion is routine. We hope to be more innovative in the future and use other kinds of online discussion to increase online students' engagement with the course.

6.3. Effect of How Students Complete the Course on Performance

Insights can be gleaned into the relationship between how the course is completed (i.e., lectures, podcasts, or other strategies) and performance in the course. Data on how students completed the course are not collected by the learning management system, the course evaluations, or any other information system. Seven months after the course was completed, a questionnaire was sent to all 493 students asking several questions, including questions about attendance at lectures and use of podcasts. One hundred and one students completed the questionnaire. Twenty-four students (i.e., $24 \div 101 = 24\%$) stated that they attended only the lectures. Fifty-nine students (i.e., 58%) stated that they completed only the podcasts. Nine students (i.e., 9%) stated that they attended lectures and completed podcasts. Nine students (i.e., 9%) stated that they did not regularly attend lectures or regularly use podcasts.

The second and third columns in Figure 7 compare the questionnaire data with learning management system data for the entire class to determine how representative of the entire class the questionnaire data are. The numerical values in these columns are the means, standard deviations, and p-values for the entire class (493 students) and the questionnaire respondents (101 students) for document usage, number of quizzes completed, and examination and course grades. With respect to document usage, there is no statistically significant difference (i.e., the p-value is greater than 0.05) in mean values between the students who completed the questionnaire and all of the students in the class. However, with respect to the quizzes and the examination and course grades, there are statistically significant differences (i.e., the p-values are less than 0.05). The mean difference in grades is about 4 marks of 100. All of this indicates that the characteristics of the questionnaire respondents are not the same as the characteristics of the entire class. On average, the questionnaire respondents are better students (in the sense of earning higher grades) compared with the entire class. Also, weaker students (in the sense of earning lower grades) are underrepresented in the questionnaire responses.

Recall our statement in Section 2 that about 20% of the class attended lectures, about 65% of the class completed the podcasts, and about 15% of the class did not regularly attend lectures and did not regularly complete the podcasts. These values were based on careful counts of students at the lectures, discussions with students, meetings with students during office hours, and email exchanges with students. The values from the questionnaire are $24 + 9 = 33\%$ attended lectures, $59 + 9 = 68\%$ completed the podcasts, and 9% did not regularly attend lectures and did not regularly complete the podcasts. We believe that these differences in values are because of the overrepresentation of better students and the underrepresentation of weaker students in the questionnaire data, and therefore, our 20%, 65%, and 15% values are reasonably accurate.

The last two columns in Figure 7 give the means and standard deviations of document usage, number of quizzes completed, and grades for the questionnaire respondents who attended only the lectures (24 students) and the respondents who used only the podcasts (59 students). These data are based on the questionnaire, but they are obtained from the learning management system. With respect to the mean documents used, the students who attended only the lectures used significantly fewer documents than the students who used only the podcasts: 36.8 versus 62.6. This is because

Figure 7. Statistical Analysis of Questionnaire Information

Course information	Mean, (standard deviation) p-value*			
	Entire class (493 students)	Questionnaire (101 students)	Lectures only (24 students)	Podcasts only (59 students)
Documents used (122)	51.6 (22.3)	55.0 (24.3)	36.8 (17.7)	62.6 (22.5)
p-values	p = 0.193		p ≈ 0.000	
Number of quizzes completed (5)	4.1 (1.4)	4.5 (1.0)	4.8 (0.48)	4.2 (1.2)
p-values	p = 0.001		p ≈ 0.000	
Exam 1 grade (100)	72.8 (17.2)	77.0 (14.1)	79.4 (13.8)	76.4 (14.4)
p-values	p = 0.009		p = 0.390	
Exam 2 grade (100)	76.2 (16.3)	80.0 (12.8)	82.3 (11.1)	79.8 (12.0)
p-values	p = 0.010		p = 0.358	
Final exam grade (100)	68.5 (15.1)	72.6 (13.5)	78.5 (13.6)	70.1 (12.4)
p-values	p = 0.007		p = 0.013	
Course grade (100)	76.2 (11.6)	79.8.1 (10.5)	83.4 (9.2)	78.5 (9.8)
p-values	p = 0.003		p = 0.033	

*The *p*-values refer to the statistical significance of the difference in means. Statistically significant differences (i.e., less than 0.05) are underlined.

the students who attended the lectures used only a small number of the 44 podcasts. They also completed more quizzes: an average of 4.8 compared with 4.2 for the students who used only the podcasts. With respect to the mean grades on the two online examinations (examination 1 and examination 2), there were no statistically significant differences between students who attended only the lectures and students who used only the podcasts. However, the differences in the mean final examination grade and final course grade were statistically significant. Figure 7 shows that these differences were fairly large. A large contributor to these differences was the ability of the students themselves; our experience in the lectures was that many of the better students attended the lectures. (This made the lectures very pleasant for the instructor.) We think that, had students been randomly assigned to either the lectures or the podcasts, then the differences would not have been significant.

Figure 8 shows cumulative relative frequency distributions of the course grade for the students who responded to the questionnaire. Students who attended only the lectures had a better course grade distribution than students who used only the podcasts. Three respondents stated that they attended fewer than 30% of the lectures and also completed less than 30% of the podcasts. We label these students "hard-to-reach," because it is hard for the instructor to reach students who do not regularly attend lectures and do not regularly use podcasts. The mean (and standard deviation) of the course grade for these students was 65.7 (and 10.0). This is much lower than the mean course grade for students attending the lectures and students using the podcasts. (Note that, because there are only three students, the differences are not statistically significant; the *p*-values are 0.10 and 0.16, respectively.) Figure 8 shows that the course grade distribution for these students is the worst. Although only three hard-to-reach students completed the questionnaire, we estimate that the total number of hard-to-reach students is about 15% of the class.

6.4. Comparison with Previous Course Design

Figure 9 compares the 2017 course described in this paper with an earlier course in 2014. Both courses were taught by the same instructor, covered the same topics, and used the same textbook. The 2014 course was traditional. There were no quizzes. There were three examinations, but none were online. About one-third of the lectures were "captured" using a classroom lecture capture system (called Echo 360) and available online to students a few days after the lectures. Two of the examinations included a one-hour period where students went to a university computer laboratory, solved two or three problems in Excel, answered several related questions, and dropped their Excel workbooks in a dropbox for subsequent grading by the teaching assistants. The 2017 course is the course described in this paper.

The enrolments for the 2014 and 2017 courses reported in Figure 9 were similar. (The 2017 course also had a class of 128 students in another term, and therefore, the total enrolment for the year was 621.) The final examinations in 2014 and 2017 were very similar. The class average on the final examination increased from 51.3 in 2014 to 68.5 in 2017. Because the online design of the 2017 course is the only difference between the 2014 and 2017 courses, we believe that it is the main reason for this large, statistically significant improvement.

Student course evaluations at the university are voluntary. Many students do not complete an evaluation, and therefore, we do not know for sure how all students value the course or assess the effectiveness of the instructor. At the university, a mean rating of 8.0 or higher is considered high. Therefore, we believe that the ratings shown in Figure 9 rightly indicate that the value of the course and the effectiveness of the instructor were high in the 2014 course (value of course: 7.97 ≈ 8.0, effectiveness of instructor: 8.37) and again,

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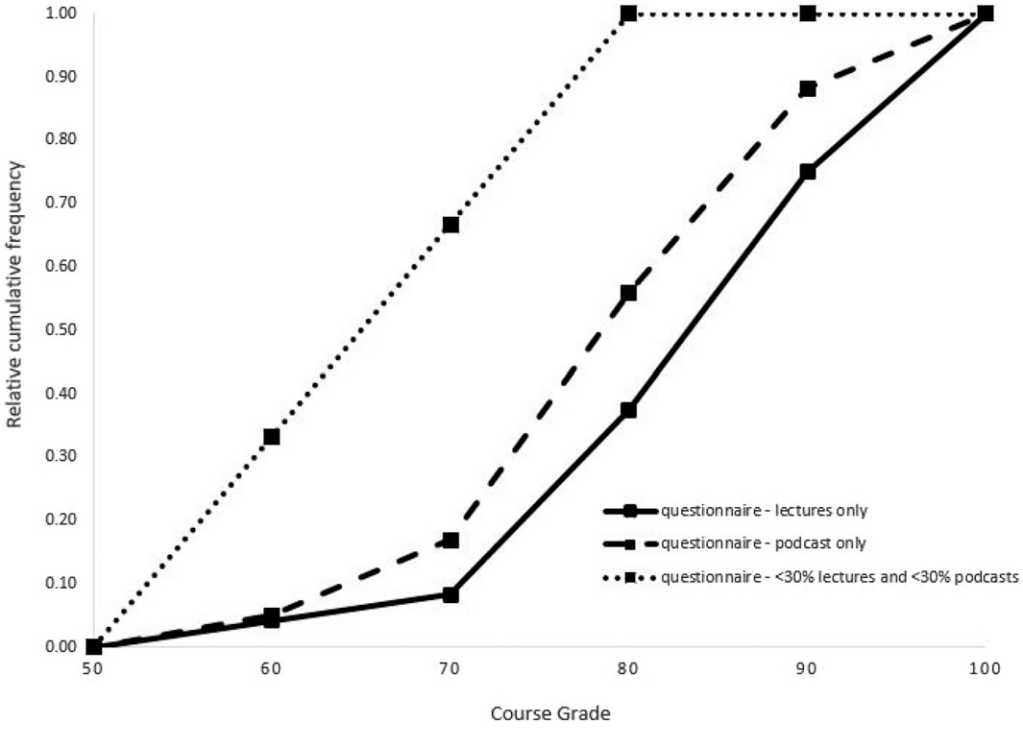
Figure 8. Effect of How the Course Was Taken on the Final Course Grade



were high in the 2017 course (value of course: 8.12, effectiveness of instructor: 8.11). Our sense of what was changing in the course from 2014 to 2017 is that the value of the course was increasing as student access to online material was increasing and that the effectiveness of the instructor rating was decreasing as students did more online work and attended fewer lectures. Unfortunately, the data, although marginally in the right direction (value of course: 7.97 in 2014 increases to 8.12 in 2017; effectiveness of instructor: 8.37 in 2014 decreases to 8.11 in 2017), do not show any statistically significant changes. This is likely because the student course evaluations were voluntary and the number of students who completed the course evaluations was low.

Student rating of instructor effectiveness is an important issue for instructors, because a decrease in the instructor effectiveness rating adversely affects faculty who need high ratings to earn tenure or receive merit pay and adversely affects contract instructors who need high ratings to earn another contract. Scherrer (2011) had the same concern: "Another concern among faculty considering teaching online courses is that their course evaluations suffer as a result." She states that, at her university, traditional courses and online courses use different student evaluation instruments and that the instructor ratings are measured differently on the two instruments. Unfortunately, our university uses the same instrument and therefore, evaluates instructors the same way for traditional and online courses. Scherrer (2011) states that, for her traditional and online courses, the instructor ratings were not significantly different. (This is the same as the result that we report in Figure 9.) Notwithstanding her result and our result, we believe that any instructor contemplating online teaching should think very carefully about how student evaluation of instructor effectiveness will be done.

Initially, we were surprised that student evaluation of the value of the course changed so little (7.97 in 2014 to 8.12 in 2017); we expected a larger change and hoped that the difference would be statistically significant. There were many written comments in the student evaluations stating that students enjoyed the online design, liked the flexibility that it gave them to study and work when and where they pleased, and were happy with the Excel skills and management science expertise that they acquired. We think that these comments are accurate for most of the class and were surprised that they did not translate into a higher student evaluation of the value of the course. We think that the main reason for this is that the value of the course was not high for the hard-to-reach students. Our experience with these students, especially during office hour visits, was that many of them were falling behind, could not catch up, and were not enjoying the course. We expect that they rated the value of the course very low. We hypothesize that the online design of the 2017 course lulled some students into thinking that they could learn the course material without doing much work. They did not attend lectures and fell behind with the podcasts. Because they were not prepared, they

Figure 9. Comparison of 2014 Traditional Course with 2017 Online Course

	2014 course (traditional)	2017 course (online)	Statistical significance
Number of students	448	493	
Final exam grade (out of 100)	mean = 51.3 variance = 135.4	mean = 68.5 variance = 227.7	p-value ≈ 0 p-value ≈ 0
Student course evaluation:			
Value of course to student (1 to 10)	mean = 7.97 variance = 4.3	mean = 8.12 variance = 4.8	p-value = 0.63 p-value = 0.59
Effectiveness of instructor (1 to 10)	mean = 8.37 variance = 3.0	mean = 8.11 variance = 4.9	p-value = 0.34 p-value = 0.03

skipped quizzes and examinations. By the end of the course, they were overwhelmed and had a lot of difficulty just passing. The variability in the instructor rating in Figure 9 provides some statistical data to support this hypothesis. The variance increased from 2014 to 2017 and was statistically significant. This increase suggests wider differences between students in 2017 than in 2014 about the effectiveness of the instructor. (The change in the variability of the value of the course, although marginally in the same direction, is not statistically significant.) Because the online design of the 2017 course is the only difference between the 2014 and 2017 courses, we believe that it is the main reason for the increase in variability. The variability in the final examination grade in Figure 9 provides similar statistical data to support the hypothesis. The variance in the 2017 final examination is higher than the variance in the 2014 final examination (and the difference is statistically significant). The increase in variability suggests wider differences between students in 2017 than in 2014 in their performance on the final examination. Again, we believe that the possibility of completing the course online is the main cause of this increase in variability.

7. Conclusion

In their required industrial engineering undergraduate management science course with a class size of about 55 students, Sharkey and Nurre (2016) augmented their traditional lectures with optional online video tutorials. They reported two potential drawbacks with their innovation: "The first was that use of the videos created an expectation that all material should be covered by a set of video tutorials … Another potential drawback is that students may be tempted to just view the videos and not attend class." We experienced both of these drawbacks in our business school course. As soon as we started posting video podcasts, students wanted more podcasts, and when podcasts were available, students skipped the lectures. Because students wanted podcasts, we created them, and because students skipped lectures, we made podcasts for them so they could learn the material that they had missed. Before we knew it, the entire course was online. Sharkey and Nurre (2016) also observed that this movement from traditional material to supplementary videos to fully online can be viewed as a movement toward "massive open online courses." We agree with this observation. It seems, for example, entirely possible that the 122 documents, 5 online quizzes, and 2 online examinations in our online course could be moved to an open platform and transformed into an open online course.

Although we are happy with the current online design of the course, we expect to make improvements. In addition to the usual improvements in lecture notes, practice problems, quizzes and examinations, and software, we hope to produce better podcasts (shorter and with better video, audio, and indexing). We believe that letting students complete all or part of the course online is good for them and good for the university. We believe that it can also be good for the instructor. Previously, when we only used traditional lectures, we found the course difficult to teach at times. Because there were so many students in the lecture hall, there were frequent interruptions when students arrived late, left early, talked to each other, asked questions related to not being able to see or hear the lecture, and did not remember material from previous lectures. Some students thought the pace was too fast and wanted fewer topics, more examples, and more reviews. Other students were bored, complained that the pace was too slow, and asked about additional topics. Podcasts made it possible to please almost all of the students. With so many students using the podcasts, there were fewer students at the lectures, which made it easier to adjust each lecture in response to students' questions. The lectures worked well for the students who attended them, and the podcasts worked well for the students who used them. We have no preference for lectures or podcasts; we like them both. Although we would not want to drop the lectures, we believe that they could be dropped and that all students could do the course online.

Preparing and maintaining podcasts and online examinations and managing an online course are a lot of work for the instructor, and that work does not automatically produce better student evaluations. In our opinion, it is more likely to produce worse evaluations if the same evaluation instrument is used for traditional and online courses. Any instructor contemplating teaching management science online should think carefully about how their work will be evaluated.

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An important concern for us is the hard-to-reach students (i.e., students who attend less than 30% of the lectures and use less than 30% of the podcasts). Changing the course design so that these students do not fall behind is a priority. One obvious change is to make the online quizzes and online examinations compulsory. We did this earlier in 2016, but many students still skipped the quizzes and examinations, claiming illness, conflicts, computer problems, etc. It was impossible to verify all of the reasons for the absences and keep track of everything. Because of this, students were allowed to miss quizzes and examinations in 2017 (and have the marks for the missed quizzes and examinations transferred to the final examination). However, this allowance made it easier for the hard-to-reach students to procrastinate and fall behind. Scherrer (2011) had the same experience: "A well-known problem of online courses is that it is easier for students to procrastinate . . . The inclusion of a weekly 'accountability point' had been quite successful in our department's previous master's level courses . . . it became clear that that was not enough for the undergraduate students . . . the weekly comprehension quiz seemed to be successful for those who took it seriously, but an alarming number of students still did not. It is unclear how to reach those students or if it is even the instructor's responsibility to do so." We want to reach as many hard-to-reach students as we can, and therefore, improving the course design for their benefit is a top priority.

Acknowledgments

I would like to thank the associate editor and two reviewers for their careful reading of the paper and thoughtful suggestions for improvements.

Appendix A. Course Content

Figure 1 lists the topics covered in the course.

Excel Review and Simple Business Modeling

At the start of the course, about 20% of the students had useful Excel skills. The rest had some understanding of Excel but could not easily format, use formulas or functions, create cell names or insert charts, install add-ins, change trust settings, etc. These Excel basics needed to be learned for the first time or reviewed before students could learn and implement management science tools in Excel. We gave students an Excel review workbook to work through and free access to online Excel tutorials at Lynda.com. For PC computers, we recommended *Excel 2013 Essential Training* or *Excel 2016 Essential Training*, both by Denis Taylor. For Mac computers, we recommended *Excel for Mac 2011 Essential Training* or *Excel for Mac 2016 Essential Training*, both by Curt Fry. Seventy-eight percent of the students used the Excel review workbook. A small number of students did some of the online tutorials.

We reinforced what students were learning in the Excel review in the simple business modeling topic. When learning business modeling, students also practiced Excel basics, including formatting, formulas, goal seek, data tables, charts, and functions for calculating statistics and other values. Only the simplest business modeling was covered. More sophisticated business modeling would be done later in the course and a subsequent elective course after students had better Excel skills and management science expertise.

The first two online quizzes and the first online examination tested whether students were doing the Excel review. After this, the Excel basics were being used regularly in the course, and it was not necessary to test students again.

Linear Programming

LP made up about 30% of the course. It was split almost evenly between

- formulation and solution (graphical and using Solver in Excel),
- formulating standard LP problems in operations, finance, marketing, and human resources, and
- sensitivity analysis (slack and surplus, shadow price, reduced cost, range of feasibility, and range of optimality).

Formulation and solution of LP problems are traditional management science tools. Seeing these tools implemented in Excel shows to students that management science is used in business (why else would Microsoft include Solver in Excel). When students see how the LP formulation and (graphical) solution are implemented in Excel using Solver, they gain confidence in their ability to use Excel. Both of these (i.e., the importance of management science and the usefulness of Excel) are reinforced with each new standard LP problem that is studied.

Teaching the graphical solution method is helpful for understanding the Solver output. It is also necessary for understanding sensitivity analysis. Sensitivity analysis is the most difficult topic in the course, and we teach it in depth. We believe that doing this shows to students that important business tools, like LP, have levels of sophistication and that these can be learned by undergraduate business students.

Decision Analysis

Decision analysis made up about 25% of the course. It was split almost evenly between

- one-stage decision problems using payoff tables,
- multistage decision problems using decision trees, and
- utility functions

One-stage decision problems are modeled using payoff tables created and analyzed in Excel. Students now have enough Excel skill to create their own payoff tables with Excel formulas to calculate values, such as maximin, Laplace equally likely, Hurwicz realism, minimax regret, expected value, value of perfect information, and value of sample information.

Multistage decision problems with decision trees enable students to analyze more sophisticated problems. This is first taught in the traditional way (on paper with pencil). Then, decision trees are entered and solved in Excel using an Excel add-in called TreePlan (www.treeplan.com). This introduces students to third-party add-ins. They learn that add-ins must be purchased, installed, and added into Excel, which involves security and trust settings. They also learn

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how important it is to know the theory behind an add-in. They see that an add-in does a lot of sophisticated work and that, because of their own Excel skills, they can format, manipulate, extend, etc. the add-in results to produce whatever reports they need.

We have used TreePlan for many years, and the students love it. It is free if a student purchases a new textbook, but most students at the university do not purchase new textbooks for their required courses. They purchase used textbooks, or they do not purchase a textbook at all. Our solution to this difficulty was to purchase an annual license from treeplan.com, which entitled each student to use TreePlan. That money is paid by the department; therefore, students get TreePlan for free. This is a great arrangement, and we are very grateful to TreePlan.

Modeling risk preference using utility functions adds a final level of sophistication to this topic. Utility functions are handled in an elegant way in TreePlan. This is another occasion when students will sharpen their Excel skills.

Simulation and Waiting Lines

Simulation and waiting lines made up the final 30% of the course. Simulation is introduced as a continuation of the simple business decision models topic presented at the beginning of the course. What is added now is uncertainty in some of the model parameters. These parameters are treated as random variables, and simulation is used to estimate probability distributions for the model output variables. Simulation extends the range of business decision models that students can analyze. Students review random numbers and learn how to use the random number functions in Excel. We also use another Excel add-in called SimQuick (www.simquick.net) to give students experience with specialized software for simulating business decision problems. SimQuick is currently free. There is a modest charge for the SimQuick user's manual, which can be purchased online. Only the most serious students in the course purchase the manual.

Another important Excel skill that is sharpened in this topic is the Excel Data Analysis add-in. We use the descriptive statistics item and the histogram item in Data Analysis to summarize and present the simulation results. Students were introduced to Data Analysis previously in a business statistics course, and therefore, using it now is an opportunity to reinforce something learned earlier. There is a difficulty with Data Analysis. It is not available in Excel 2011 on a Mac computer. It is available in Excel 2016 on a Mac and in all versions of Excel on a PC. Because about 25% of the students use Excel 2011 on a Mac, these students are not able to practice Data Analysis on their computers. Therefore, the quizzes and examinations do not require students to use Data Analysis to solve problems; instead, we only ask descriptive questions about Data Analysis. This will change in the future when students with a Mac computer no longer use Excel 2011. Instructors should not require all students with Mac computers to upgrade to Excel 2016. When the class size is very large, there will be many students who are unable or unwilling to upgrade, and this will cause difficulties for the instructor, especially at examination times.

The final topic studied in the course is waiting line or queuing models. This is presented as a business decision model with uncertainty (i.e., simulation) that, because of its special structure, can more easily be analyzed using a waiting line model. We review the usual introductory material and then, depending on how much time is left in the course, study as many of the MM1, MMs, MD1, MG1, and MMsN models as possible. Excel worksheets for each waiting line model are used.

Appendix B. Learning Management System

Avenue to Learn is the name of the secure, university-wide, internet-based learning management system used at the university. It is where we post documents, conduct online discussions, administer tests, collect assignment submissions, and maintain grades. Avenue to Learn is built and hosted by Desire2Learn, an educational technology company headquartered in Kitchener, Ontario, Canada. Before 2010, the university used a system from BlackBoard Inc. Figure B.1 shows the home page for the management science course.

There are several tabs across the top of the home page: Content, Resources, Communication, Assessments, etc. These tabs take students to various pages. The course documents are at the Content tab (Figure B.2). Figure B.2 shows four documents for the week of January 13–20. The first document is a pdf file (notice the special icon) of the notes for Lectures 5–8a. The second file is an Excel workbook containing worksheets for the problems in the lecture notes. The last two files are mp4 video files. The first of these is a podcast of Lectures 5 and 6a; the second file is a podcast of Lectures 6b–8a. Clicking on either gives the student the option to stream or download the podcast.

The third tab is Communication. This goes to several pages, including the discussion forum, where students, teaching assistants, and the instructor post and answer questions. A list of frequently asked questions is maintained there. The fourth tab is Assessments (Figure B.3). This is where students access the five online quizzes and two online examinations, assignment drop boxes for the online examinations, and the grades page where they monitor their grades.

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Figure B.1. Management Science Course Homepage in Avenue to Learn

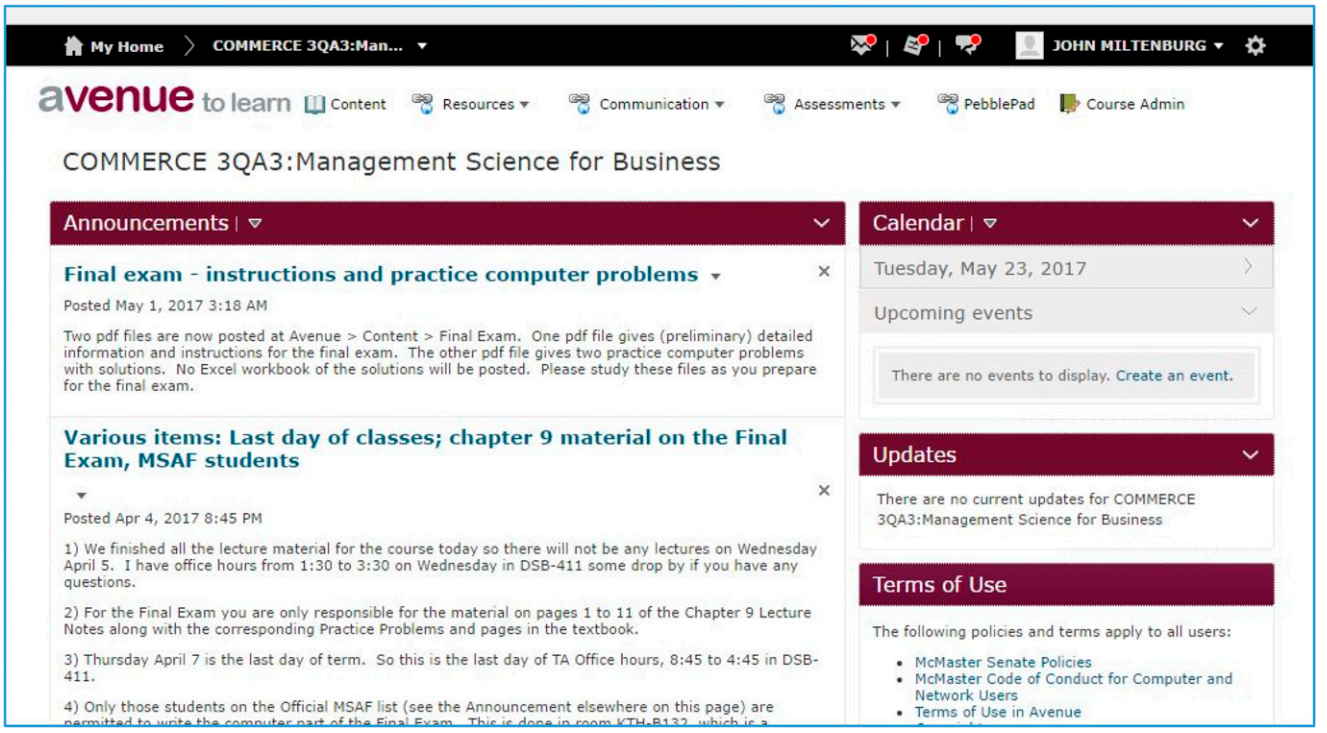


Figure B.2. Content for the Week of January 13–20

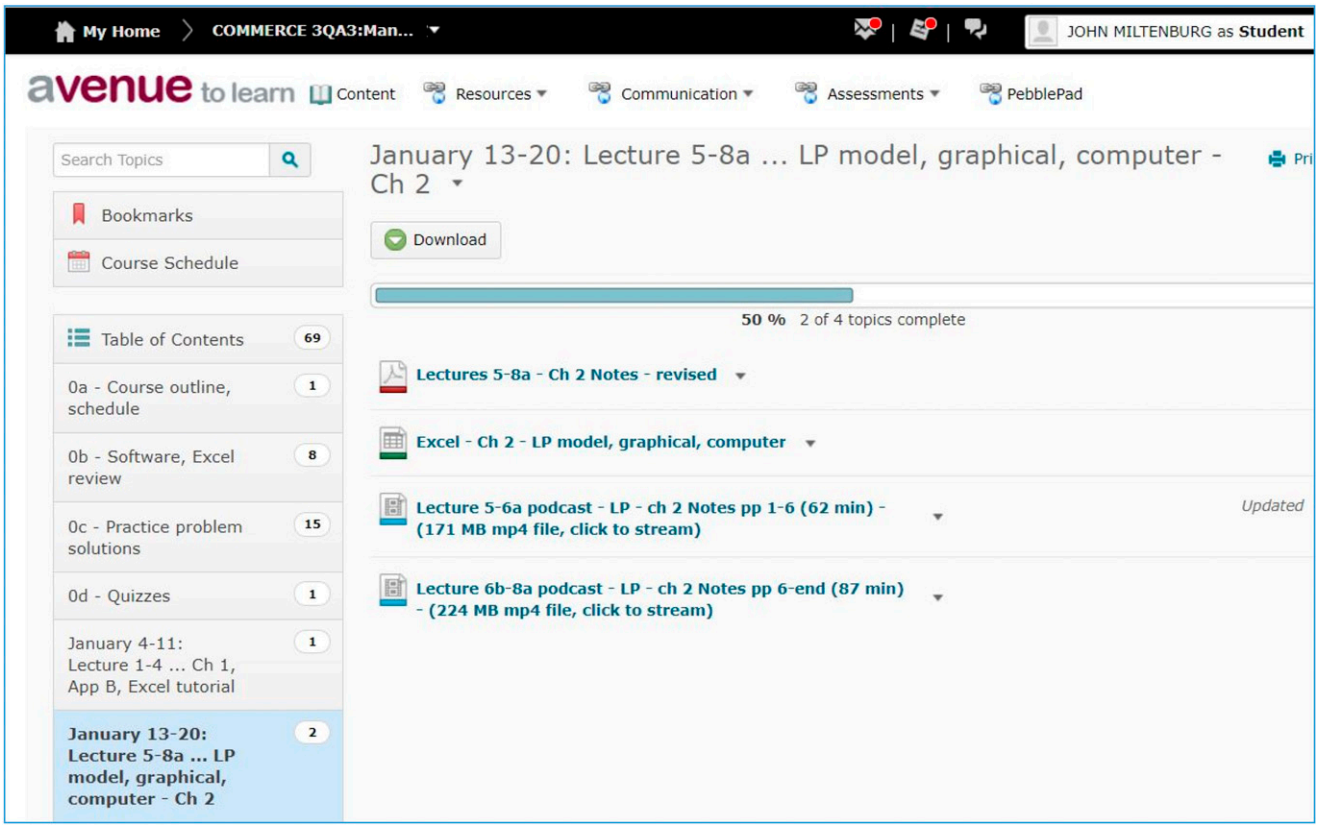
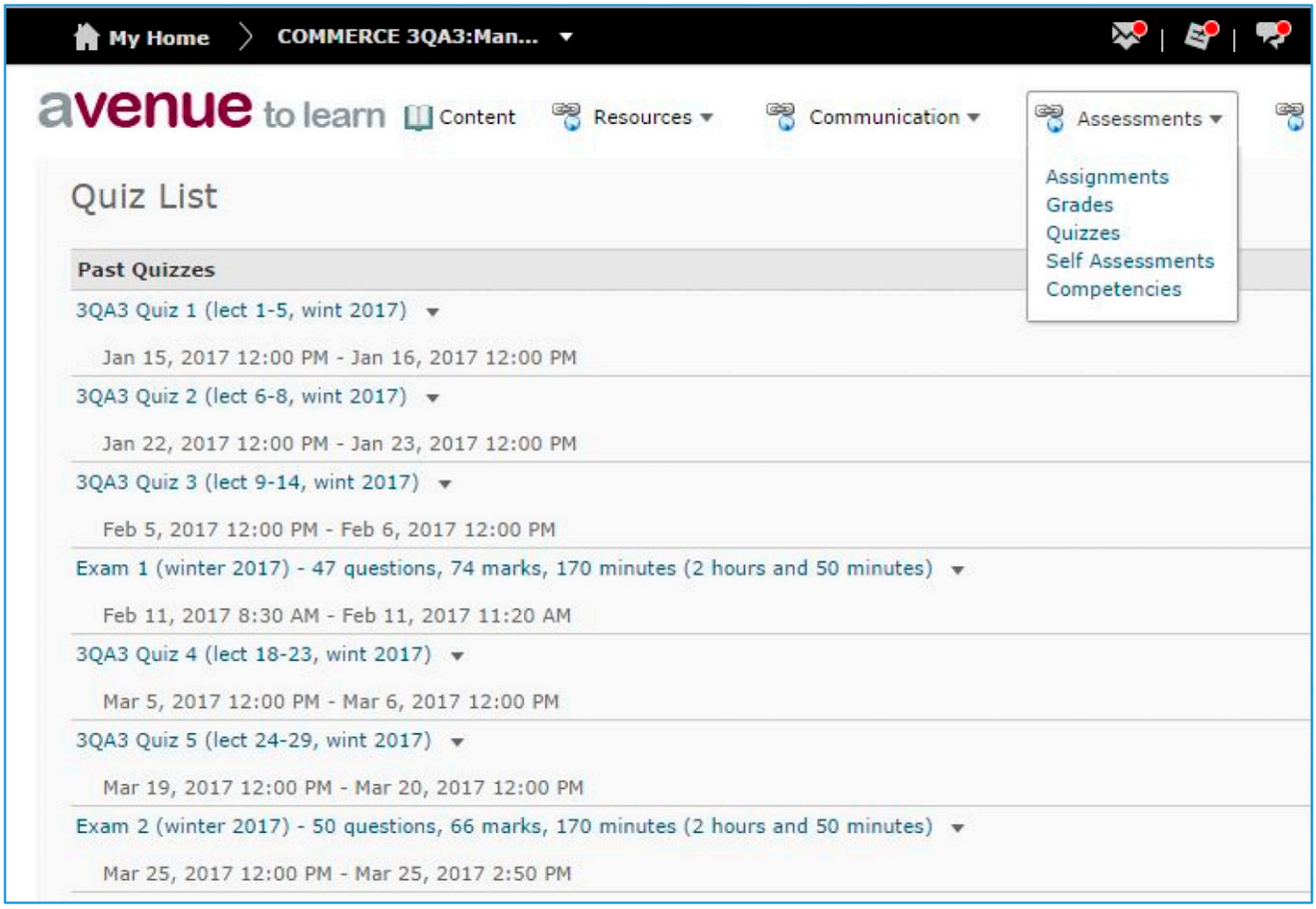


Figure B.3. Assessments Page



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