

ASSESSMENT OF ESSAYS IN A MANAGEMENT SCIENCE COURSE

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ABSTRACT

The ability to communicate a problem statement and an appropriate quantitative business method are important professional skills. This paper presents an analysis of student skill in writing a final exam essay that describes how a specific organization can improve decision making using mathematical programming, the business modeling approach that was the focus of the course. Although performance on assessments of professional writing and the description of a mathematical programming model averaged less than 80% across all essays written, improved writing when students received formative feedback in 2013 suggests that teaching students to identify and articulate the development and use of business tools through written communication is an important area for future business research.

Keywords: Management Science, Assessment, Writing, Business Education

INTRODUCTION

Business managers must combine both critical thinking and communication skills. As part of AACSB Standard 15, Management of Curricula, all undergraduate and graduate business students are expected to develop knowledge and skills in General Business and Management (AACSB 2014). To address this requirement, the management science course is required of all Management and Management Information Systems majors at the authors' university. At the end of an undergraduate management science course, the instructor assessed the students' ability to describe how to solve a realistic problem using mathematical programming, the business modeling approach that was the focus of the management science course. A final exam essay assessed the students' ability to identify and discuss relevant principles from management science to address a problem described for a specified business. This paper summarizes student performance on this learning outcome gathered in management science classes taught during the fall 2010, 2011, 2012, and 2013 semesters. The summary illustrates how the instructor used assessment data to inform decisions about teaching and learning. In particular, assessment findings from the first three years of data collection (2010-2012) documented weaknesses in student writing for professional

communication. The instructor modified course instruction strategies to provide students with more feedback about their writing. Assessment data gathered in this final year assessed and documented the impact of this change on student learning.

This paper explores how well students are able to articulate how a specific organization can use a mathematical programming model to aid in decision making. The first author assessed student essays with respect to the quality of professional writing and the adequacy of the description of a business model. Students were expected to identify business decisions, write a statement of the business objective, describe constraints, and write potential follow-up questions for sensitivity analysis in a final exam essay.

The educational complexity level of the final exam essay can be evaluated in terms of Bloom's taxonomy. Bloom's taxonomy is a multi-level model that has been used to describe different levels of complexity of student learning in an educational environment. An updated version of Bloom's taxonomy was developed by Anderson and Krathwohl in 2001 that slightly modified the levels. Lowry, Showalter and Merrill (2014) and Stanny (n.d.) present a set of action verbs that identify verbs for each level in the taxonomy using language that students and faculty understand. Some components of the final exam essays represent the *understanding* level of the taxonomy, which is defined as constructing meaning from written messages through categorizing, grouping, and paraphrasing. Students at this level are required to identify business decisions, identify the business objective and describe the constraints. In the final exam essay, students are required to move to the highest level of the taxonomy, which entails organizing the elements of the problem and generating new elements. For example, when students write recommendations for the sensitivity analysis component, they must generate their own follow-up question(s).

In the management science course, students learn how to interpret business word problems by developing a legend with variable symbols for business decisions and using the legend to generate a mathematical objective function and mathematical expressions for constraints (Anderson, Sweeney, Williams, Camm, & Martin, 2011). Throughout the course, students learn how to develop a variety of mathematical programming models, including linear programming, integer programming, and mixed integer programming models. Students learn to use computer software to solve their mathematical programming models and write a recommendation based on their results. Students learn how to write business memos about the business word problem in terms of the decisions, objective, and constraints, as well as their recommended solution (Williams, Stanny, Reid, Hill, & Rosa, 2014). Students also learn to answer follow-up questions about changes in resource constraints, minimum requirements, new requirements, or changes to decision contributions to the objective. Literature about teaching linear programming primarily focuses on effective strategies for teaching the mathematical components of linear programming (Liberatore & Nydick, 1999; Stevens & Palocsay, 2004). However, students should be able to imagine and describe the use of mathematical programming for a given organization by the time they complete a management science course. This paper describes one instructor's assessment of student writing on a final exam essay that required students to write about how management science procedures

might be used in practice. After documenting consistent problems with student writing (2010-2012), the instructor examined evidence-based practices for improving student writing, implemented new instruction in 2013, and gathered additional assessment data to evaluate the impact of the new teaching strategy.

In the fall 2013 semester, students wrote an additional essay: one new essay in response to a question on the last quiz prior to the final exam that included an essay. The essay question on the last quiz provided students with written feedback and supported a class discussion on business writing prior to the final exam. Essay results based on the last quiz and final exam performance in this class are presented. In the course, the memo homework assignments and the extra quiz essay represent the implementation of multiple teaching strategies: students experience distributed practice (students write multiple memos during the term and a last quiz essay), repeated testing (both the memo assignments and the extra quiz essay are graded), and receive formative feedback on their writing and analysis. Feedback intended to promote student learning must be specific and must be combined with an opportunity for students to use the feedback to improve performance on subsequent work (Nichol & Macfarlane-Dick, 2006). Repeated practice with formative feedback can produce significant improvement in skill. For example, Stanny (2013) provided feedback by using a common rubric to evaluate a series of reflective essays and encouraged students to use feedback on early essays to improve subsequent submissions. Quality of writing and students' use of evidence to support arguments improved significantly across a series of five reflective essays. Dunlosky, Rawson, Marsh, Nathan, and Willingham (2013) reviewed ten learning techniques and evaluated the quality of evidence documenting their benefit for student learning. The strategies described for the management science course include methods that Dunlosky et al. identify as having strong empirical support: distributed practice, which creates multiple practice opportunities spread out over time, interleaved practice, which introduces variation in problem type through a series of problems scheduled to create distributed practice, and practice testing, in which multiple self-tests or practice tests provide feedback about the quality of learning. Although most instructors focus on the value of tests and other assessments to determine and document student learning, these assessments are also important learning tools (Arnold & McDermott, 2013; Putnam & Roediger, 2013).

METHOD

Approval for data collection and analysis was granted by the first author's university Institutional Review Board. Students enrolled in the fall 2010, fall 2011, fall 2012, and fall 2013 undergraduate management science courses taught by the first author received letters of invitation in the initial class lectures and were asked to consent voluntarily to participate in the study by allowing inclusion of their class performance data in the analysis. The assessment summarized in this paper is based on a total of 88 participants. Since 80 participants were seniors (students with more than 90 semester hours) and only 8 participants were juniors (students with 60-89 semester hours), the class rank could not be analyzed separately while protecting student anonymity. Table 1 summarizes the total course enrollment, the number of students who consented to participate,

and the distribution of majors and gender characteristics of students included in the data pool each semester. Based on the data from Table 1, Chi-Square tests were performed with the enrollment and subject groups with respect to major and gender. Table 2 summarizes the Chi-Square tests, which reveal that the variations in the distribution of numbers of majors and genders for the participants who enrolled in these classes each year represent the random variation expected from the distributions of major and gender of students in the enrollment population.

Table 1

Distribution of Major and Gender of Students Enrolled in the Course and Students Who Consented to Participate each Year

	Total Course Enrollment (%)				Participants (%)			
	2010	2011	2012	2013	2010	2011	2012	2013
Major								
Management	21 (70)	24 (73)	19 (70)	11 (73)	20 (69)	17 (70)	15 (65)	9 (75)
Other	9 (30)	9 (27)	8 (30)	4 (27)	9 (31)	7 (30)	8 (35)	3 (25)
Gender								
Women	6 (20) 24	13 (40) 20	10 (37) 17	2 (13) 13	6 (21) 23	10 (42) 14	9 (39) 14	2 (17) 10
Men	(80)	(60)	(63)	(87)	(79)	(58)	(61)	(83)
Total	30	33	27	15	29	24	23	12

Table 2

Summary of the Calculated Values for Chi-Square Computed for Demographic Comparisons Each Year

Year	Major	Gender
2010	0.007	0.004
2011	0.025	0.030
2012	0.152	0.023
2013	0.010	0.059

Note. All values for $\chi^2(3)$ are non-significant

Beginning in the first week of the semester, class discussion introduced students to the analysis of business word problems and effective business communications using a memo format. All four homework assignments used a business memo format; students were required to write response

memos that described their decisions and articulated objective, constraints, recommended course of action to the original problem, and comments regarding revised recommendations in response to additional sensitivity analysis questions. Student homework performance data were collected throughout each semester on building mathematical programming models and writing memos (Williams, Stanny, Reid, Hill, & Rosa, 2014).

At the end of the course, the students took a cumulative final exam. The final exam included traditional word questions that required students to formulate separate linear programming and mixed integer programming models as well as an essay question that asked students to describe the use of management science concepts and analysis to solve a problem faced by a particular organization. Examples using organizations, such as UPS (United Parcel Service), were discussed in an exam review in class each semester. The instructor discussed expectations for appropriate answers, such as articulating the decisions, an objective, constraints, and sensitivity analysis questions. The essay question for the exam administered in fall 2013 is presented below.

Explain how a linear program, integer program, or mixed integer program from management science can help a CVS pharmacy with a specific example. Your explanation should demonstrate learning the concepts covered in class over the semester. Write legibly, with correct spelling and grammar.

The case analyzed in exam essays changed each year, but all essay questions required students to demonstrate their skill with the same management science analysis tools. For example, the questions used on the final exams in fall 2010, fall 2011, and fall 2012, and the last quiz in fall 2013, required students to discuss how a linear program, integer program, or mixed integer program can help the US Army, a veteran's hospital, a Ford (car) dealership, or a university bookstore, respectively.

RESULTS

The instructor assessed student performance for the student essays based on the quality of professional writing, the clarity and accuracy of the description of a mathematical programming model, and the value of sensitivity analysis. Two aspects of the essay were assessed: business analysis content and quality of writing. Specifically, the essay content required the student to describe business decisions appropriate for a mathematical programming model, state an appropriate business objective, describe at least two constraints, and pose at least one meaningful follow-up question for sensitivity analysis. The first author evaluated student writing with an analytic rubric, according to the rubric classifications defined in Riddle and Smith (2008). The rubric is summarized in Table 3. The evaluation of essay writing was based on general writing quality such as correct grammar, spelling, and coherency. If the student had at most one writing error, they earned the maximum writing score of 5 points. If they made two, three, four, five, six or more mechanical writing mistakes, then they earned 4, 3, 2, 1, or 0 points, respectively. The

exam is timed and students are given about three-fourths of a page to write their essay. As a result, students write approximately five to eight sentences in their essays.

Table 3
Components of the Rubric for the Essay Question

Aspect	Description	Points
Content	Decisions	2
	Objective	2
	Constraints	4
	Sensitivity Analysis Question	1
Writing	Mechanics of Writing	5

The average scores for student essay assessments are presented in Figure 1. The average total student performance on the essays was below 80% across all four years. When the content and writing scores are examined separately (presented in Figure 1), the average student essay content score exceeded 80% only in 2013 (the year when the quiz essay with feedback was implemented).

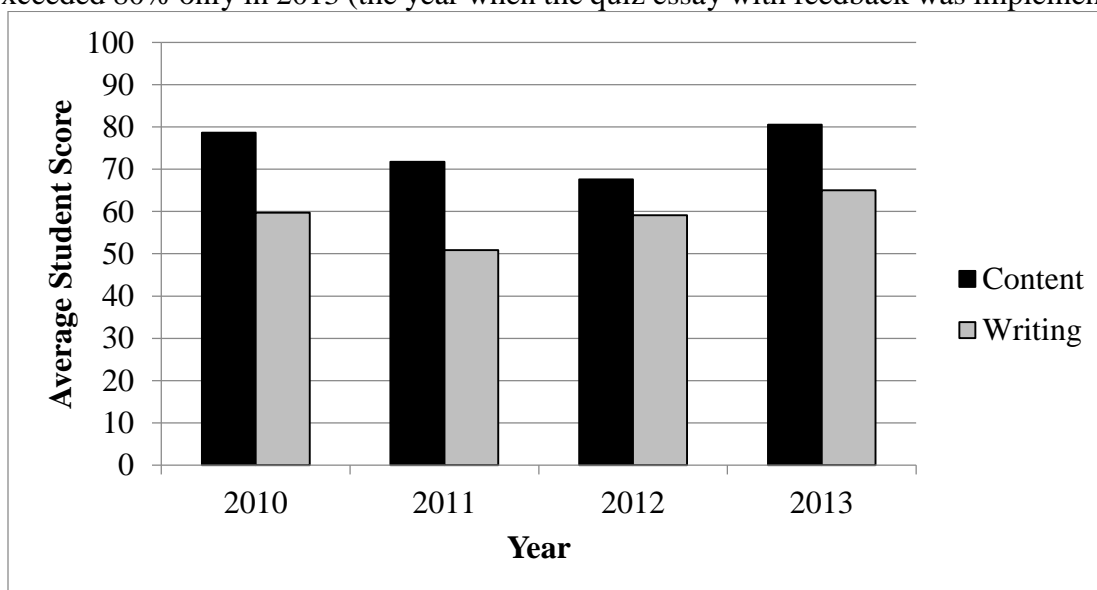


Figure 1. Average Essay Score in Terms of Content and Writing.

Statistical analyses were performed on the average student final exam essay scores for content versus writing over time for fall semester classes 2010, 2011, and 2012, using IBMS SPSS Version 22. A one-way between groups ANOVA was conducted to compare the average student final exam essay content assessment scores for three different years. There was not a significant effect of year on the average student final exam essay content scores, $F(2,75) = 2.965$, $MSE = 275.602$, $p = .058$. Likewise, a one-way between groups ANOVA was conducted to compare the average student final exam essay writing assessment scores for fall semester classes 2010, 2011, and 2012.

There was not a significant effect of year on the average student final exam essay writing scores, $F(2,75) = 1.001$, $MSE = 616.864$, $p = .372$. Thus, the three classes were combined to form a single group representing all students enrolled between 2010 and 2012.

Figure 1 illustrates a significant need to improve student writing performance on essays, documented in assessment data collected between 2010 and 2012. To address this need for improvement in student learning the instructor implemented an instructional change in fall 2013 that focused on providing students with feedback about their writing. Prior to the final exam, the instructor added an essay question to the last of four quizzes, administered in week 15 of the 16 week course. As discussed in the first section of this paper, this opportunity to write an essay twice was consistent with research in the literature on effective strategies for promoting student practice in writing. Students received their graded last quiz with written comments about their performance on both essay content and writing. It should be noted that the course syllabus allows for the lowest of the four quizzes to be dropped. Figure 2 shows the performance on essays for the last quiz versus the final exam.

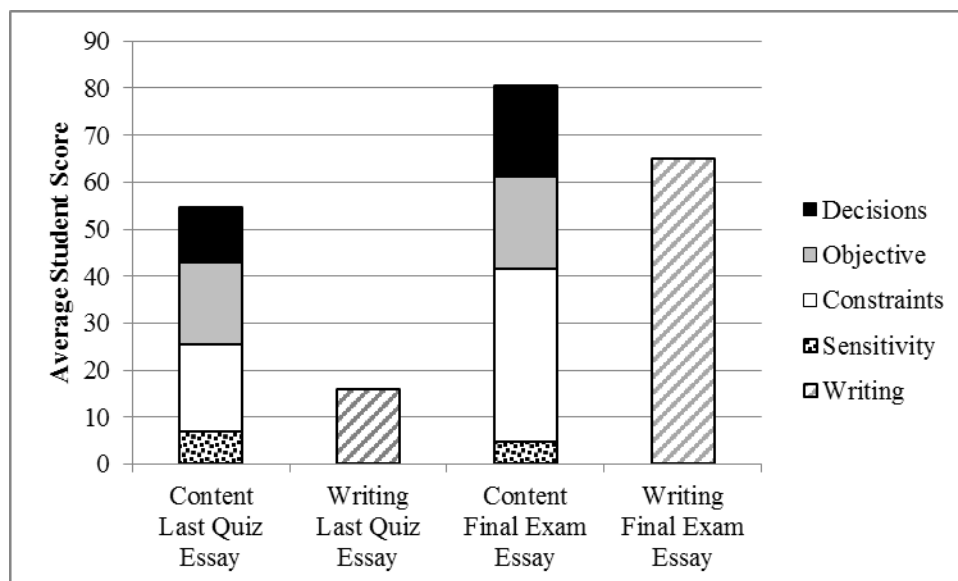


Figure 2. Average 2013 Essay Scores for Last Quiz versus Final Exam in Terms of Content (Four rubric elements: Decisions, Objective, Constraints, Sensitivity,) and Writing (One rubric element).

Statistical analyses compared the average student final exam essay content scores for the 2010 to 2012 final exams (for three course sections) to the 2013 final exams followed by a similar analysis for the final exam essay writing scores, using Megastat Version 10.2. A *t*-test for independent groups and unequal variances compared the average content student final exam essay score for 2010 to 2012 to the average for 2013. As shown in Table 4, the 2013 content mean was

higher than the 2010 to 2012 content mean and there was a significant difference in the average student scores for final exam essay content.

Table 4

Comparison of Final Exam Essay Content Scores for Students Enrolled in 2010 to 2012 versus 2013

Year of Enrollment	Mean Score	Standard Deviation
2010 to 2012 (N=76)	73.15	17.031
2013 (N=12)	80.56	12.646

Note. Contrast is statistically reliable ($t(17) = -1.788, p = .046$).

Table 5 presents the results for the average student final exam essay writing scores for the 2010 to 2012 final exams versus the 2013 final exams. Again, a *t*-test for independent groups and unequal variances compared the average writing student final exam essay score for 2010 to 2012 versus 2013. As shown in Table 5, although the 2013 writing mean was higher, the standard deviations were very high and one cannot conclude that there was a significant difference.

Table 5

Comparison of Final Exam Essay Writing Scores for Students Enrolled in 2010 to 2012 versus 2013

Year of Enrollment	Mean Score	Standard Deviation
2010 to 2012 (N=76)	56.75	24.84
2013 (N=12)	65.00	24.31

Note. Contrast is not statistically reliable ($t(14) = -1.089, p = .147, ns$).

Figure 2 calls for an examination of the average student final exam essay content versus writing scores for the 2013 last quiz as well as for the 2013 final exam. These analyses are followed by further comparisons between the 2013 last quiz and final exam essays. These four comparisons are summarized in Tables 6 to 9, which contain the results of four *t*-tests performed using SPSS Version 22.

The *t*-test results for the average content versus the average writing assessments for the last quiz are presented in Table 6. Table 6 shows that the 2013 last quiz content mean and 2013 last quiz writing mean are significantly different. This result is not surprising given the difference between the 2013 last quiz content versus writing means illustrated in Figure 2.

Table 6

Results of t-test To Compare the Content versus Writing on the 2013 Last Quiz (N=12)

Test Instruments	Mean Score	Standard Deviation
2013 Last Quiz Content	54.63	30.78
2013 Last Quiz Writing	15.83	26.10

Note. Contrast is statistically reliable ($t(21) = 3.330, p = .002$).

Next the *t*-test results for the average content versus the average writing assessments for the 2013 final exam are presented in Table 7. Table 7 shows that the 2013 final exam content mean and 2013 final exam writing mean are also significantly different. Again, this result is anticipated given the difference illustrated in Figure 2.

Table 7

Results of t-test To Compare the Content versus Writing on the 2013 Final Exam (N=12)

Test Instruments	Mean Score	Standard Deviation
2013 Final Exam Content	80.56	12.65
2013 Final Exam Writing	65.00	24.31

Note. Contrast is statistically reliable ($t(16) = 1.967, p = .033$).

Table 8 provides the results for a *t*-test comparing the average content scores for the 2013 last quiz versus the 2013 final exam. Table 8 shows that the average 2013 final exam content score is significantly higher than the average 2013 last quiz content score. Students improved their ability to identify the components of a problem and model following the feedback provided with the 2013 last quiz.

Table 8

Results of t-test To Compare the Content on the 2013 Last Quiz versus the 2013 Final Exam (N=12)

Test Instruments	Mean Score	Standard Deviation
2013 Last Quiz Content	54.63	30.78
2013 Final Exam Content	80.56	12.65

Note. Contrast is statistically reliable ($t(14) = -2.699, p = .009$).

Table 9 provides the results for a *t*-test comparing the average writing scores for the 2013 last quiz versus the 2013 final exam. Table 9 shows that the average 2013 final exam writing score is significantly higher than the average 2013 last quiz writing score. Students improved their writing about the components of a problem and model following the feedback provided with the 2013 last quiz.

Table 9

Results of t-test To Compare the Writing on the Last Quiz versus the Final Exam (N=12)

Test Instruments	Mean Score	Standard Deviation
2013 Last Quiz Writing	15.83	26.10
2013 Final Exam Writing	65.00	24.31

Note. Contrast is statistically reliable ($t(21) = -4.776, p = .000$).

Our analyses reveal that the means for the mechanics of writing are significantly lower than the means for the essay content for both the last quiz and the final exam in 2013 as shown in Tables 6 and 7. Both the content and the mechanics of writing means are higher on the final exam than the last quiz in 2013 as shown in Tables 8 and 9. Our results indicate that the fall 2013 instructional changes, which included the extra practice with the last quiz essay, the detailed feedback from the instructor for the last quiz essay, and the class discussion when the last quiz essay was returned in class, had a positive impact on the average student performance on the final exam essay. Our results are consistent with earlier studies that found a relationship between feedback with repeated practice and improved performance (Dunlosky, Rawson, Marsh, Nathan, and Willingham, 2013; Nichol & Macfarlane-Dick, 2006; Stanny, 2013). Despite the significant improvement, the 2013 student essay means are still below 81% on both content and the mechanics of writing, so future research directions abound as discussed next.

CONCLUSIONS AND FUTURE RESEARCH

In conclusion, our results show that student writing and critical thinking, as demonstrated through describing a problem and modeling approach, remain areas in which additional research is needed to improve student performance. Assessing student writing and student ability to describe a problem and modeling components is challenging but necessary to help students advance in their business education. Furthermore, the actual final exam essay averages show an opportunity for further innovation to improve student performance.

Further research is needed to determine what factors influence student preparation and learning with respect to imagining the use of management science to solve real business problems. The results point to opportunities to conduct further research to determine how to improve student learning on the discussion of the use of business tools to aid decision-making.

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