

Assessment of Student Memo Assignments in Management Science

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Frequently in Management Science courses, instructors focus primarily on teaching students the mathematics of linear programming models. However, the ability to discuss mathematical expressions in business terms is an important professional skill. The authors present an analysis of student abilities to discuss management science concepts through memo homework assignments. The findings indicate that average student grades on homework problems for linear programming formulations were always higher than average student grades on homework memos in which they write about their formulations. These results suggest that teaching managerial writing about analytical work is an important area for future business education research.

Keywords: assessment, business education, management science, managerial writing, memos

Two important areas of learning in business education research include how to develop managerial communication skills (Alatawi, 2012; Grossman, Norback, Hardin, & Forehand, 2008; Williams & Reid, 2010) and how to improve student skills in problem solving (Aiken, Martin, & Paolillo, 1994; Anderson, Kimes, & Carroll, 2009; Boatwright & Stamps, 1988; Kimball, 1998). Our university chose to require all management and management information systems majors to complete a course in management science (among other courses) to ensure student learning for the 2013 Association to Advance Collegiate Schools of Business (AACSB) Standard 8, Curricula Management and Assurance of Learning (Standard 15 in 2003), and the 2013 AACSB Standard 9, Curriculum Content (Standard 16 in 2003), which includes expectations for knowledge in the areas of General Business and Management (AACSB, 2013).

The management science course helps students learn how to describe the complexities and logic of real-world

business problems to improve decision making. In an introductory undergraduate course in management science, students learn first how to identify decisions in a word problem and translate them into a legend with variable symbols. Using their legend, students learn how to translate the word descriptions for the objective and the constraints into an objective function and mathematical expressions, respectively (Anderson, Sweeney, Williams, Camm, & Martin, 2011). Words to numbers is a contemporary label for this important skill, which can also be described as level two (comprehension) in Bloom's Taxonomy (Anderson & Krathwohl, 2001; Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Krathwohl, 2002). When an assumption of linearity is appropriate, students are taught to use mathematical constructs to develop a linear program. Once students learn to use computer software to solve and interpret the relationship between the optimal solution and the constraints, they learn to write a memo restating the problem and their recommendation based on the optimal solution from their model. This memo communication can be described as level 4 (analysis) or level 5 (synthesis: production of a unique communication) in Bloom's taxonomy (Anderson & Krathwohl, 2001; Bloom et al., 1956; Krathwohl, 2002).

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TABLE 1
Course Demographics

Characteristic	Total course enrollment (%)								Participants (%)							
	2010		2011		2012		2013		2010		2011		2012		2013	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
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	13	40	10	37	2	13	6	21	10	42	9	39	2	17
Men	24	80	20	60	17	63	13	87	23	79	14	58	14	61	10	83
Total	30		33		27		15		29		24		23		12	

Most pedagogy related to linear programming focuses on teaching students the mathematics of linear programming (Liberatore & Nydick, 1999; Stevens & Palocsay, 2004). Research in the pedagogy of mathematics describes the strategies students must learn to use to translate word problems into mathematical expressions (Barnes, Perry, & Stigler 1989; Grinde & Kammermeyer, 2003; Koedinger & Nathan, 2004; Rittle-Johnson & Koedinger, 2005, Williams & Reid, 2010). An important learning goal is that students will be able to articulate their skills, discuss management science procedures, and translate the results into recommendations for business problems.

The development of expert skill requires multiple opportunities to practice a skill in which later practice is guided by and benefits from the formative feedback individuals receive on earlier performances (Ericsson, Krampe, & Tesch-Römer, 1993). Designing multiple assignments enables students to practice key academic skills, receive formative feedback, and apply this feedback to improve their performance on subsequent assignments (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Feser, Vasaly, & Herrera, 2013; Khan, Khalsa, Klose, & Cooksey, 2012; Stanny & Duer, 2013; Thompson, Nelson, Marbach-Ad, Keller, & Fagan, 2010).

Here we describe the development of student writing through practice with memo homework assignments and present data on student performance for both the modeling and writing portions. Business students may develop the skill labeled words to numbers when they define the problem in a business memo and build the model, whereas students may develop the skill labeled numbers to words when they write a business memo to communicate a recommendation based on their model. An added advantage of these assignments is that they motivate students to engage with important mathematical concepts and course writing outside class. These assignments prepare students for active, engaging discussions during class that clarify and deepen student mastery in these

areas to improve persistence and student learning (Braun & Sellers, 2012; Nelson Laird, Chen, & Kuh, 2008; Strangman & Knowles, 2012).

METHOD

Participants in the study were students enrolled in the fall 2010, fall 2011, fall 2012, and fall 2013 undergraduate management science courses taught by Julie Ann Stuart Williams. The university Institutional Review Board approved data collection and analysis. The analysis is based on a total of 88 participants, where eight were juniors, students with 60–89 semester hours, and 80 were seniors, students with 90 or more semester hours, including a minimum of 20 semester hours of course work at the junior/senior level. The sample size of juniors was too small each term to analyze data separately while protecting student anonymity. Students were recruited for the study through an invitation to participate voluntarily, letters of invitation were distributed and informed consent forms were collected during the first and second class lectures. The total course enrollment each term and the number of students who consented to participate that term are shown in Table 1 along with descriptive data on the characteristics of students included in the data pool in terms of major and gender. Using the data from Table 1, chi-square tests were performed for each year with the enrollment and participant groups with respect to major and gender. The chi-square tests shown in Table 2 demonstrate that the variations in the distribution of numbers of majors and men and women

TABLE 2
Summary of the Calculated Chi-Square Values per Year

Year	Major (<i>df</i> = 1)	Gender (<i>df</i> = 1)
2010	0.007	0.004
2011	0.025	0.030
2012	0.152	0.023
2013	0.010	0.059

TABLE 3
Summary of Elements Included in Homework Assignment Assessment Tools

	Tool															
	Homework 1				Homework 2				Homework 3				Homework 4			
	Year (201_)				Year (201_)				Year (201_)				Year (201_)			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Decisions	2	2	2	2	5	4	3	4	8	16	9	9	9	23	13	12
Problem type																
LP product mix	x	x	x	x	x	x	x	x								
LP network									x	x	x	x				
IP													x	x	x	x
MIP													x	x	x	x
Objective																
Max profit	x	x	x	x	x	x	x					x	x	x	x	x
Max units					x			x				x				
Min cost		x					x	x	x	x	x	x	x	x	x	x
Constraints																
Capacity	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Demand	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Contracts	x	x						x								
Budget				x	x	x		x								
Management preferences				x	x	x	x	x	x	x	x	x		x	x	x
Flow balance													x	x	x	x
Setup													x	x	x	x

Note: There are three categories (problem type, objective, and constraints) with subcategories (3, 3, and 7 respectively) listed below each category. LP = linear programming; IP = integer programming; MIP = mixed integer programming.

enrolled in these classes each year represent the random variation expected from classes drawn from the same underlying population.

During the first week of the semester, students were introduced to the memo format for homework assignments in class discussions and a course packet that included complete examples of memo homework assignments and memo keys from previous semesters. The first author evaluated student performance on new memo homework assignments developed for that semester. Homework assignment performance was evaluated with a rubric, which evaluated student performance on several writing components, including the memo, legend, objective function, and identification of constraints. The memo section of the rubric included the student’s description of the problem including the decisions, the objective, and the constraints; their recommendation; their response to sensitivity analysis questions; their professionalism including grammar and appearance of document pages; and the attachment of an appendix with supporting documentation. Other sections of the rubric evaluated the mathematical aspects of linear programming such as the formal legend and the mathematical expression of the objective function and the constraints.

The homework assessment tools are summarized in Table 3. An x in Table 3 indicates that a homework assignment assessed that skill. Each of the four homework

assignments had two problems. The number of decisions in the assignments ranged from two to 23, as noted in Table 3. The objectives were not always financial. For example, in the second homework for fall 2010, one of the problems required students to maximize the units of product produced as a small business prepared to sell their product at a local festival. The types of constraints considered are summarized in Table 3 to demonstrate the variety of limits or requirements imposed by the business scenarios. The expected procedure for all homework assignments was that students would use computer software to discover an optimal solution.

Homework solution key memos include the summary statement of the decisions, the objective, the constraints, the recommendation, and the objective function value for the recommended solution. An example of the first problem of the first homework memo and solution key for fall 2012 is given in Appendices A and B, respectively, to demonstrate the quality expected for student writing in the assignments. Examples of homework memo solution response keys for fall 2010 were presented in a conference paper (Williams, Stanny, Reid, Martin, & Mateeva, 2012). Solution keys for homework assignments were distributed to the students in class on the day the assignment was due. The solution key then became the focus of the lecture discussion that day. Thus, the homework assignments prepared students for active discussion and elaboration of concepts in management science, representing an implementation of

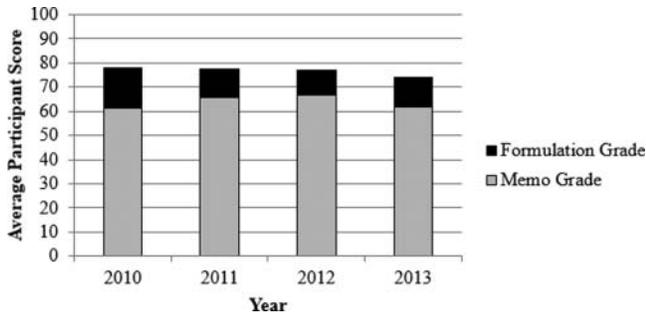


FIGURE 1. Average scores earned on homework assignments (contributions of formulations and memo writing about formulation components).

flipped or inverted classroom pedagogy (Lage, Platt, & Treglia, 2000; Tucker, 2012; Wilson, 2013).

RESULTS

Average student performance for the homework model component (a mathematical linear programming formulation) and the homework memo component were tracked over time, as shown in Figure 1. Interestingly, average student scores were always higher for the formulation component than for the memo writing component. The formulation average evaluated the students’ abilities to build a linear programming model that included creating legends to define decision variables, objective functions, and constraints. Writing the memo required students to write about the decisions, objective, constraints, interpretation of their model, and their recommendation. Other test instruments that evaluated mathematical programming knowledge such as quizzes and exams are not included in the analysis in this article.

Statistical analyses were performed on the average student scores for each type of assessment, formulation versus writing, and over time for each fall semester class by year, using IBM SPSS Version 19. To compare the average student formulation assessment scores for different years, a one-way between-groups analysis of variance (ANOVA) was conducted. There was not a significant effect of year on the average student formulation assessment scores, $F(3, 84) = .179, MSE = 51.658, p = .911$. Likewise, to compare the average student writing assessment scores for different years, a one-way between-groups ANOVA was conducted. There was not a significant effect of year on the average student writing assessment scores, $F(3, 84) = .530, MSE = 178.875, p = .663$. Thus, the four classes were combined for a paired-samples *t*-test to compare the performance for type of assessment, formulation versus memo writing. There was a significant difference in the average student scores for formulation ($M = 77.1845, SD = 16.7609$) and writing ($M = 64.1458, SD = 18.2199$), $t(87) = 12.077, p < .001$. These statistical results for the average student scores for the type of assessment are consistent with the differences between formulation grade and memo grade illustrated in Figure 1.

TABLE 4
Paired Samples Correlations Between Formulation and Writing Grades

Year	<i>n</i>	Correlation value	Significance
2010	29	.838	.000
2011	24	.922	.000
2012	23	.666	.001
2013	12	.871	.000

Furthermore, when examining the performance per class, paired samples correlations between formulation and writing were high as shown in Table 4. Students with higher formulation averages had higher memo writing averages. However, the memo writing averages were not as high as the formulation averages as discussed in a previous paragraph.

For further evaluation, the average scores for each of the four homework assignments for the model component (a mathematical linear programming formulation) and the memo component were tracked over time, as shown in Figure 2. Each homework assignment had two problems with two memos, which are aggregated in Figure 2. Figure 2 is graphed to compare student memo writing versus student formulation of the mathematical model for the same assignment. For each homework assignment, average student scores were always higher for the formulation component than for the memo writing component. Because the lowest homework grade was dropped, the effect of earning a score of zero on one or more homework assignments greatly impacted the variability in Figure 2. The percentages of students earning a zero on the fourth homework were 45%, 38%, 35%, and 50% for the 2010, 2011, 2012, and 2013 classes, respectively. A potential source of variability for 2012 was that Hurricane Isaac caused the university to be closed for two days, which meant students in fall 2012 had one less class lecture from the unit before the second homework assignment was due.

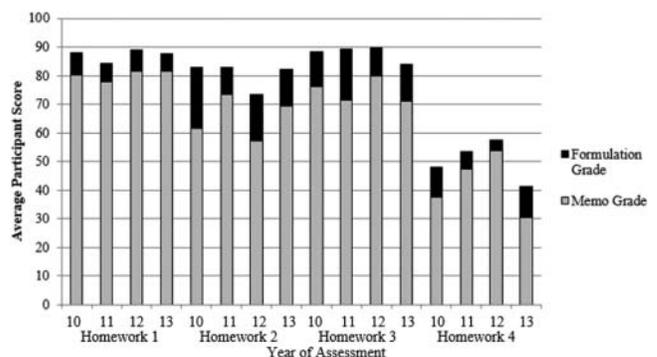


FIGURE 2. Average scores earned on individual homework assignments (contributions of formulations and memo writing about formulation components).

Another source of variability is that the homework assignments became more challenging as the course progressed. As shown in Table 3, the first homework assignment required students to model simple two-decision problems whereas subsequent homework assignments required the students to identify many more decision variables. In Figure 2, the first homework assignment consistently had averages in the mid to high 80s. Figure 2 also shows that the third homework required the student to build clearly structured network models with capacity, demand, and management preference constraints. In Figure 2 the student performance on the LP Formulations for the third homework consistently had averages close to 90. For the simpler first and third homework assignments, there is little room for improvement on average student performance for the simpler formulations. However, there is more room for improvement for student performance for writing about their simpler formulations since Figure 2 shows lower average scores on writing the memos for the first and third homework assignments.

Figure 2 illustrates that average performance was worst for writing about the more complex and less structured models in the second and fourth homework assignments. On the other hand, student performance was higher when they discussed the two-decision model in the first homework assignment (a simpler problem) and the more structured network flow models presented in the third homework assignment. Because mixed integer programming is the most challenging course concept, lower average performance for the fourth homework formulations and memo writing are evident in Figure 2, as anticipated. Thus, Figure 2 indicates an important area for future researchers to improve student learning about analytical communication of simpler and more complex problems.

CONCLUSIONS AND FUTURE RESEARCH

In conclusion, these results show that average student performance with respect to writing business memos about even simple two-decision or highly structured network flow linear programming models can be improved. For more complex, less structured problems, average student performance for writing business memos can be improved significantly. Interestingly, Figure 2 shows that average student writing scores were always lower than average student formulation scores for the same problem scenarios in all four homework assignments. These results point to opportunities for further innovation to improve student writing in business memos.

As employers seek candidates who can perform and communicate analytical work, these results suggest that additional research is needed to develop and assess teaching methods that will help students write about their business analyses. Different types of business situations require

different types of business communication skills (Bean, 2011; Sigmar & Hynes, 2012; Zhu, 2004). Faculty may need assistance to improve their understanding of student backgrounds, including prior business course experiences and existing writing abilities to integrate writing across the curriculum (Bacon & Anderson, 2004; Bacon, Paul, Johnson, & Conley, 2008; Bean, 2011; Plutsky & Wilson, 2001; Sigmar & Hynes, 2012). Consistent with these results, business writing should be integrated into multiple business courses to teach students the business context, improve critical thinking, and develop associated business writing skills necessary for success.

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APPENDIX A: EXAMPLE FIRST PROBLEM, FIRST HOMEWORK ASSIGNMENT MEMO WITH WORD PROBLEM FOR FALL 2012

MEMO

DATE: August 30, 2012

TO: MAN 3550 Management Scientist

FROM: Bree Green, Production Manager; Patriotism, Inc.

CC: Cedric Count, Controller; Sam Spender, Procurement Manager; Gerry Grow, Marketing Manager

RE: Product Mix for Patriotism, Inc. (Assignment 1, Problem 1, due September 13)

How many of each of two sizes of flags should Patriotism, Inc. produce in order to *maximize* total profit? The following departments have provided helpful information. Please submit your recommendation at the start of class on September 13.

Production

There are two sizes of flags which require the labor time and materials per flag as shown in Table A1.

Human Resources

The cost for each type of specialist in \$/hour is given in the table above. The hours available for each specialist are also given in Table A1.

Marketing

At least 250 of the large flags and at least 325 of the medium flags must be produced. Each large flag sells for \$20 and each medium flag sells for \$15.

TABLE A1
Production and Cost Data for Example Homework 1 Assignment Memo With Word Problem for Fall 2012

Labor and materials per flag	Cost per unit	Large	Medium	Resources available
Labor				
Cutting	\$9/hour	5 minutes/flag	4 minutes/flag	60 hours
Sewing	\$9/hour	8 minutes/flag	6 minutes/flag	80.5 hours
Tagging	\$9/hour	2 minutes/flag	2 minutes/flag	40 hours
Material				
Fabric	\$2/yard	2 yards	1.5 yards	3000 yards
Thread	\$0.15/yard	6 yards	4 yards	Unlimited

TABLE B1
Cost Calculations for Example Homework 1 Assignment Memo With Word Problem for Fall 2012

Total cost calculations	Cost per unit	Size large		Size medium	
		Number of units	Cost	Number of units	Cost
Labor					
Cutting	\$9/hour	5	\$0.75	4	\$0.60
Sewing	\$9/hour	8	\$1.20	6	\$0.90
Tagging	\$9/hour	2	\$0.30	2	\$0.30
Materials					
Fabric	\$2/yard	2	\$4.00	1.5	\$3.00
Thread	\$0.15/yard	6	\$0.90	4	\$0.60
Total cost/flag			\$7.15		\$5.40
Price/flag			\$20.00		\$15.00
Profit/flag			\$12.85		\$9.60

APPENDIX B: EXAMPLE RESPONSE MEMO FOR FIRST PROBLEM FIRST HOMEWORK ASSIGNMENT SOLUTION KEY FOR FALL 2012

MEMO

DATE: September 13, 2012

TO: Bree Green, Production Manager; Patriotism, Inc.

FROM: MAN 3550 Management Scientist

CC: Cedric Count, Controller, Sam Spender, Procurement Manager, Gerry Grow, Marketing Manager

RE: Product Mix for Patriotism, Inc. (Assignment 1, Problem 1)

In response to your query to determine the number of each size flag to produce to maximize profit, I investigated the resources available in terms of specialist labor including cutting, sewing, and tagging as well as the fabric supply. I also considered the marketing requirements to produce at least 250 of the large flags and at least 325 of the medium flags as well as the selling price of \$20/large flag and \$15/medium flag. I developed a linear programming model that is detailed in Attachment 1. Also included in Attachment 1 is the Management Scientist software output for my model. (The software output is not included in this paper to conserve space).

Based on my model with an objective to maximize profit, I recommend the following product mix:

Produce and sell 360 large flags

Produce and sell 325 medium flags

The total profit from producing and selling this combination of flags is \$7,746.

Attachment 1: Model for Patriotism, Inc. Product Mix

The cost and profit calculations are shown in Table B1.

Legend

X1 = # of large flags produced and sold

X2 = # of small flags produced and sold

Objective Function

MAX 12.85X1+9.6X2 Maximize profit

Constraints

- 1) $5X1+4X2 \leq 3600$ Cutting labor available (minutes)
- 2) $8X1+6X2 \leq 4830$ Sewing labor available (minutes)
- 3) $2X1+2X2 \leq 2400$ Tagging labor available (minutes)
- 4) $2X1+1.5X2 \leq 3000$ Fabric supply (yards)
- 5) $1X1 \geq 250$ Marketing requirement (large flags)
- 6) $1X2 \geq 325$ Marketing requirement (medium flags)
- 7) $X1, X2 \geq 0$ Non-negativity requirement

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