ABSTRACT

This study analyzes student performance between different teaching treatments of course material delivery: 15-week face-to-face semester (Traditional), 6-week face-to-face summer session (Summer) and 15 week online semester (Online) in a graduate introduction to operations management course. Results reveal no significant differences in student performance for the three different teaching treatments. Implications for instructors and computer managed systems may exist.

Key Words: online course delivery, traditional course delivery, student performance

INTRODUCTION

As more programs and courses transition to the online environment, instructors need to evaluate the relevance of the various evaluation methods utilized to measure student performance especially as they relate to the introduction and enhancement of technology. The various methods (e.g. homework, quizzes, exams, case studies, etc.) should augment student learning. Certainly it is technology that is an enabler of the variety of online programs (e.g. 100% online, hybrid & blended) that exist today. Students taking at least one online course increased by 560,000 students from spring 2010 to fall 2010 (Allen and Seaman, 2011). Additional research needs to be conducted in the online domain and to understand the worth of course-support materials (Biktimirov and Klassen, 2008).

LITERATURE REVIEW

While it is a common perception among instructors that homework improves students’ abilities, knowledge and retention, this is not always true. It is believed that by assigning homework students are able to ‘learn by doing’ and this will help students in studying and preparing for exams and other assessments (Rayburn and Rayburn, 1999). Yet, the relationship between homework and student performance are not consistent. A study of an accounting course (Rayburn and Rayburn, 1999) and a first year financial accounting course (Eskew and Faley, 1988) confirmed a positive relationship between homework and performance. On the other hand, a study of an introductory operations management class (Peters, Kethley & Bullington, 2002) found that there was no significant relationship between required homework and performance on a multiple choice exam. Therefore, the discussion concerning the relationship between homework and the performance of students remains.

The view that online ancillary materials can enhance student performance is supported by empirical research. However, the results for online homework are mixed (Smolira, 2008). For
the purpose of this research, online homework is defined as exercises and problems that are contained within the software package that is provided with the course textbook. These exercises and problems are completed by the student by accessing the textbook website and completing the instructor assigned exercises and problems. The positive relationship between online homework and performance have been found in an introductory finance course (Biktimirov and Klassen, 2008) and in a chemistry class, student performance was significantly better with online homework versus a control group (Arasasingham et al., 2005; Arasasingham et al., 2011).

On the other hand, several studies have found indifferent or negative results regarding online homework and performance. Examples include: no significant differences between classes that used online homework and those that used text-based homework in the traditional written format in the sciences (Cole and Todd, 2003) or in physics (Bonham, Beichner and Deardorff, 2001; Bonham, Deardorff, and Beichner, 2003). Others noted weak correlations between online homework and student performance on examinations (Fisher and Holme, 2000; Chamala et al., 2006). Another study showed that student performance in online statistics and economics courses produced inferior learning outcomes relative to the traditional environment (Anstine and Skidmore, 2005). Researchers did not detect any significant differences in predicting student success for several Web-based homework systems for teaching undergraduate business statistics (Palocsay and Stevens, 2008). Students using online computer-generated math homework did not perform better on examinations; however, students’ success rate in the overall course grade appears to be better than the traditional homework group (Kodippili and Senaratne, 2008). In essence, there is conflicting evidence relating to the effectiveness of online homework which highlights the need for further investigation (Arasasingham et al., 2011). Due to these conflicting results caution should be employed especially considering the differences between instructors, instructional methods, prior student knowledge, technical ability, learning styles, and media differences (Horspool & Lange, 2012).

Several benefits, to both students and instructors, of online homework versus paper-and-pencil methods include:

- Immediate feedback which can increase student performance (Kulik & Kulik, 1986).
- Algorithmic problems can reduce the possibility of student copying (Smolira, 2008).
- Algorithmic problems allow multiple opportunities for practice (Arasasingham et al., 2011).
- Instructional methods can be modified or concepts clarified based upon feedback on student learning (Arasasingham et al., 2011).
- Less time is spent grading homework.
- Algorithmic problems create a new and different set of problems on each topic, modify them with each student log in, make the students think and encourage them to really understand the material (Arasasingham et al., 2011).

Regarding online homework, researchers are in the early stages of exploring the new technology’s effect in the educational setting and individual differences. While the majority of academic leaders believe that learning outcomes of online education are the same or superior to those in traditional face-to-face education (Allen & Seaman, 2013), critics argue that online education does not replicate the learning that occurs in the traditional classroom (Bejerano, 2008). In a comparison of graduate and undergraduate performance on online homework, graduate students performed significantly better than undergraduate graduate students (Fish, 2012).
While various studies explored the value of homework to the learning environment, further research into its value at the secondary education level remains. Thus, homework questions versus the types of questions used on exams is an area that requires further research.

RESEARCH QUESTIONS

The primary purpose of this paper is to investigate whether or not there are differences among student performance depending on the delivery method employed by the course instructor. A single instructor, over the course of three (3) semesters taught the same graduate operations management course under different delivery methods. During one semester the course was taught in an evening MBA program over a 15 week semester employing a face-to-face methodology. Over the summer semester, the same course was taught. This summer session, taught in the evening, also employed a face-to-face methodology but was completed in a 6-week time period. The last course offering was conducted in a traditional 15 week semester but was delivered entirely online. Each of the courses employed the online homework system provided by the text book manufacturer. Details of each course are provided in the Method section. The approach taken in this study is to explore the effects of different teaching methods on open-ended and scaffold quantitative problems. Open-ended problems explain a situation and pose a question without the benefit of additional information or the guidance of multiple parts. Scaffold problems contain several parts and methodically break down a problem for analysis. This points students to the solutions. (Note, given today's technology, computer software programs use scaffold problems. Open-ended problems may be developed by the instructor but cannot be graded by the computer.) To that end this investigation poses the following questions:

Research Question #1: When answering open-ended questions, is student performance different among students who are enrolled in a 15-week face-to-face evening course (‘Traditional’) versus a 6-week face-to-face evening course (‘Summer’) versus a 15-week online (‘Online’) course?

Research Question #2: When answering scaffold questions, is student performance different among students who are enrolled in a 15-week face-to-face evening course (‘Traditional’) versus a 6-week face-to-face evening course (‘Summer’) versus a 15-week online (‘Online’) course?

Research Question #3: Is student performance on scaffold questions different from student performance on open-ended questions?

METHOD

Over the course of three semesters (spring, summer and fall), three (3) sections of a graduate-level introduction to operations management course in the masters of business administration program were taught by the same instructor. The same textbook was employed and the content coverage was identical. One of the learning objectives for the course includes:

- MBA graduates will apply quantitative methods in management science.

Chronologically the ‘Traditional’ section was the first course taught. For this treatment, the course was delivered face-to-face during the evening over the course of a traditional, 15-week
semester. The course started at 600 pm and concluded at 845 pm and was held once per week during the week. A standard lecture format, employing power point presentations and chalk & blackboard to demonstrate problems was employed. After problems were demonstrated in class, students were provided with representative practice problems via the textbook online software. These problems were not graded and did not contribute to the overall course grade. However, the incentive for students was that the listed practice problems were representative of the midterm and final exam questions. The midterm and final exam had similar formats in that the exams consisted of a combination of multiple choice, essay and calculation types of problems. The calculation section contained two (2) problems. One an open ended question and the other a scaffold type of question. It is these questions that are used to judge student performance in this study. Each question was scored out of 10 points per the rubrics contained in the appendices. This was typical of all three (3) treatments. These questions represented 40% of each exam grade. Exams were proctored by the instructor and were administered during the normal class time. For each exam there was a 2 hour time limit. The class size was twenty-eight (28) students.

The next course taught was the ‘Summer’ section. This course was essentially identical to the ‘Traditional’ section except for the fact that it was delivered two times per week from 600 pm to 915 pm during the week and the duration of the course was six (6) weeks. Practice problems, the midterm exam and final exam were identical to those assigned in the ‘Traditional’ section. Exam were proctored by the instructor and administered with a 2 hour time limit. Twenty-two (22) students were enrolled in the Summer section.

The ‘Online’ section was delivered during a standard 15 week semester but was entirely online. To facilitate a virtual classroom setting, students were invited, but not required, to attend an online lecture that was facilitated by online meeting software utilized by the College. During these virtual lectures the instructor narrated the power point lecture slides in much the same manner as conducted in a face-to-face environment. Via the online meeting software, students could ask and answer questions similar to that in a face-to-face course. In order to demonstrate problems, the instructor employed a webcam so that students could see and hear the problem solving process. The lectures were recorded and posted to the College’s learning management system. This recording was available to all students whether or not they attended the online session. Practice problems were also assigned to the ‘Online’ students. However, a subset of the practice problems was required to be completed as they were a portion of the overall course grade. This subset counted 5% of the course grade. Over the course of the semester, a total of nine (9) graded problem sets were completed. This is the same number of assignments for the ‘Traditional’ and ‘Online’ treatments. Since the course was administered completely online, a modification to the midterm and final exams was made as face-to-face proctoring was not possible. Each exam was segmented into three (3) different sections: multiple choice, essay and calculation. Each section could be completed independently of the other. During the week of midterms and finals, students were provided a time window during which they could access each section of the exam. However once they accessed an exam section, there was a time limit as to how long the questions would be available. Students were informed of this well in advance so that they could appropriately prepare. For the calculation section, which contained the open ended and scaffold questions students had a total of fifty (50) minutes. This time was arrived at as being representative of the time afforded students in a face-to-face setting. This section represented 40% of the exam grade as was the case for the ‘Traditional’ and ‘Summer’ sections. A total of twelve (12) students registered for the ‘Online’ course.
To test the performance across the three treatments a common question was given for each of the exams. One question of each type was given on the midterm and final exam. These questions are contained in the Appendices. A rubric (included in the appendices) was created to maintain consistency across the treatment methods.

RESULTS

The midterm and final exams were administered at the same relative times throughout each semester. That is, the same course material was covered on each of the respective exams.

In order to determine whether or not there were differences between the midterm exam questions and final exam questions, a test was performed that compared the results of each of the exams. While it was not intended for there to be differences, the results of the test indicated a significant difference at the $p < 0.001$ level. Since the question scores (i.e. performance) on the midterm exam questions and final exam question were different (Midterm (8.56 out of 10) > Final (6.65 out of 10)), the results for each exam will be applied to each of the research questions. See table 1 for details.

**TABLE 1. AVERAGES AND STANDARD DEVIATION BY EXAM TIME ACROSS ALL TREATMENTS**

<table>
<thead>
<tr>
<th></th>
<th>Midterm</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>8.56 ***</td>
<td>6.65 ***</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.97</td>
<td>2.69</td>
</tr>
</tbody>
</table>

*** $p < 0.001$

Table 2 contains the averages and standard deviations for each question type and for each exam. All of the results are not significant. Typically when results of a study are not significant, the study is not considered successful. However in this case the occurrence of non-significant results is a positive finding. In this study, course material was delivered with three different treatments. Certainly the ideal situation would be that regardless of course delivery methodology that student learning would take place. These results support this.

**TABLE 2. AVERAGES (STANDARD DEVIATION) BY TREATMENT AND QUESTION TYPE (MIDTERM & FINAL EXAMS)**

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Traditional</th>
<th>Summer</th>
<th>Online</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MIDTERM EXAM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaffolded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Breakeven)</td>
<td>9.48 (1.02)</td>
<td>9.10 (1.51)</td>
<td>9.00 (1.58)</td>
</tr>
<tr>
<td>Open-ended</td>
<td>7.82 (2.07)</td>
<td>8.48 (1.62)</td>
<td>6.92 (3.23)</td>
</tr>
<tr>
<td><strong>FINAL EXAM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaffolded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(EOQ)</td>
<td>6.59 (1.59)</td>
<td>7.38 (1.72)</td>
<td>7.08 (2.81)</td>
</tr>
<tr>
<td>Open-ended</td>
<td>5.95 (3.15)</td>
<td>6.92 (3.62)</td>
<td>6.25 (2.90)</td>
</tr>
</tbody>
</table>
Research question #3 investigated the difference between the question types by treatment. As expected, performance on scaffold problem types was better than performance on open-ended types of problems regardless of treatment. Please see Table 3.

**TABLE 3. AVERAGES AND STANDARD DEVIATION BY QUESTION TYPE ACROSS ALL TREATMENTS**

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Open Ended</th>
<th>Scaffold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>7.10 **</td>
<td>8.11 **</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.89</td>
<td>2.01</td>
</tr>
</tbody>
</table>

**DISCUSSION AND CONCLUSIONS**

The purpose of this research is to add to the developing literature regarding different delivery methods for course material. As mentioned in the literature review, the delivery of course material via online instructional methods is growing at a rapid pace. It is incumbent upon instructors and institutions of higher learning to assure that learning takes place regardless of the course delivery method. This preliminary research demonstrates that learning, as assessed by student performance on scaffold and open ended questions, is equivalent across the three (3) studied treatments. It should be noted that the instructor made every attempt to replicate the ‘Online’ environment to that of the face-to-face environments. The primary method by which this was attained was the holding of a ‘virtual’ classroom via online meeting software. During these sessions, students could ask and answer questions in a similar manner to that in a face-to-face classroom setting. Since online instruction is new to instructors and students alike, many do not have a ‘frame of reference’ from which to build upon. All of us, instructors and students, have a frame of reference for face-to-face classrooms as that is the setting to which we were exposed during our academic training. The instructor also participated in an online course development program that was offered through their institution and the online class was the third time using online instruction. Although student performance was equivalent across the treatments, the low level of question scores may indicate that alternative teaching methods may be necessary.

This research also finds that there are differences between student performance on open ended and scaffold types of questions. This result is not surprising in that most of the online homework systems of today reflect a scaffold problem type by design. For the online homework system that accompanied the textbook utilized in the subject courses, the student is prompted to answer a particular question and if the question is answered correctly, they are then prompted to provide information related to a different part of the problem. While this affords the student instant feedback, it does not necessarily reflect a ‘real-life’ situation where the problem solver must perform the appropriate steps without prompting. While this is a current weakness of current online homework systems, it also represents an opportunity for the creators and designers of these systems to create an open ended question type of software.

A troubling result is the performance of students with respect to the midterm and final exam. As can be seen in table 1 student performance on the midterm exam was significantly greater than that on the final exam. Closer examination of this result indicates that this holds true across the question type. For the midterm exam the average score for the scaffold question type was 9.25 and on the final exam the result was 6.82. This is significant at the $p < 0.001$ level. Likewise, for
the open ended questions midterm performance (7.87) was significantly greater than final performance (6.35) at the $p < 0.01$ level. This result requires further investigation to determine why these differences exist. One potential explanation is that the course material in the second half of the course is in fact more difficult and thus these results reflect the differences in the difficulty of the course material. Another possible explanation reflects that fact that at the end of the semester exams are given by all the courses that are being taken. When the midterm is administered, perhaps the exam timing differs by a week or two thus relieving the time and preparation pressure that students may feel. Perhaps students were more stressed during final exams than they were during the midterm time period. Students who performed well on the midterm may have become over confident while those who did not perform well on the midterm may have experienced more stress due to the pressure to perform better than they did on the midterm. Additionally students who performed well on the midterm may not have adequately prepared as they felt as though they had already secured an acceptable course grade and chose to devote their time to other activities.

There are limitations to this study that should be addressed in future research. First, differences among the students were not taken into account. Students in each of the sections self-selected and were a reflection of their progress in the curriculum and their personal and/or work schedule. However it should be noted that all students, having been admitted to the program, possessed minimum academic requirements of the program. For the face-to-face sections (‘Traditional’ & ‘Summer’), the practice problems were not required to be completed by the students. They did not contribute in a direct way to the course grade. However in the ‘Online’ section, the practice problems constituted five percent (5%) of the course grade. While not a significant percentage of the course grade, it may make a difference. Future research should eliminate the inclusion of practice problems in calculation of the course grade in the ‘Online’ method. The sample size of this preliminary investigation is quite small. Twenty-eight (28) students were included in the ‘Traditional’ method while twenty-two (22) and twelve (12) comprised the ‘Summer’ and ‘Online’ sections respectively. Another possible limitation is related to the fact this online course was not proctored by the instructor. As a proxy for proctoring, a time limit was established for each question type so as to limit an ‘open book’ mentality by the students.

While these results are preliminary and require more analysis, current results indicate that differences do not exist among the different course delivery methods. Future research activities include replicating this study (i.e. increasing the sample size), and evaluating student performance on multiple choice and essay types of questions. However as noted above there are limitations to this study so the results must be interpreted carefully.

APPENDICES

Appendix 1 Midterm, Open-ended Question, Solution and Rubric

A bottling machine fills bottles with red fountain pen ink. An employee collects three samples, each with four observations, of the amount of ink filled in a bottle by the machine. The data collected, in milliliters of ink, is given below.
Sample #1: 50.9, 51.5, 49.6, 49.1
Sample #2: 49.0, 49.1, 49.0, 49.5
Sample #3: 51.0, 51.2, 51.4, 49.6
Is the process in control for 3-sigma limits? Show all work.
SOLUTION

R_1 = 2.4; R_2 = 0.5; R_3 = 1.8. Thus, average range = 1.566

Sample means: for sample 1 = 50.275; for sample 2 = 49.15; for sample 3 = 50.8

Grand mean, or process mean = 50.075

Range Chart:

- Sample size = n = 4. So, D_4 = 2.28 and D_3 = 0.
- UCLR = D_4 x (average range) = 2.28 (1.566) = 3.570
- LCLR = D_3 x (average range) = 0 (1.566) = 0

Process is in control for range chart.

Mean chart:

- Sample size = n = 4. So, A_2 = 0.73
- UCL = Process mean + (A_2)(average range) = 50.075 + (0.73)(1.566) = 51.218
- LCL = Process mean - (A_2)(average range) = 50.075 - (0.73)(1.566) = 48.931

Process is in control for mean chart.

Thus, we can say that the process is in control.

RUBRIC

Total = 10 points.

Range Chart: 1 point each for average range, UCL, and LCL. [3]
Mean Chart: 1 point each for process mean, UCL, and LCL. [3]
Correctly interpret range chart: 2 points, 1 for calculation and 1 for interpretation [2]
Correctly interpret mean chart: 2 points, 1 for calculation and 1 for interpretation [2]
Choose p or c chart: get zero credit in problem
If student calculates X-bar values: 1 point
Wrong n: minus 1.5
Minus 0.5 for each calculation error
Minus 1 for using individual data points rather than X-bar values in determining if the process is in or out of control.

Appendix 2 Midterm, Scaffold Break-even Question, Solution and Rubric

A firm’s manager must decide whether to make or buy a certain item used in the production of microwave ovens. Making the item would involve annual equipment leasing costs of $200,000. Cost and volume estimates are as follows:

<table>
<thead>
<tr>
<th></th>
<th>MAKE</th>
<th>BUY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual fixed cost</td>
<td>$200,000</td>
<td>None</td>
</tr>
<tr>
<td>Variable cost per unit</td>
<td>$40</td>
<td>$60</td>
</tr>
<tr>
<td>Annual volume (units)</td>
<td>16,000</td>
<td>16,000</td>
</tr>
</tbody>
</table>

(a) Given these numbers, should the firm make or buy this item?
(b) At what volume would the manager be indifferent between making and buying?
(c) What is the total cost for the volume in (b)—that is, at the point at which the manager is indifferent between making and buying?
(d) A new forecast indicates that annual demand will be 25,000 units. What should the manager do – make or buy – and why?

Show all work.

SOLUTION

(a) TC for MAKE = FC + VC = 200,000 + (40)(16,000) = $840,000
TC for BUY = FC + VC = 0 + (60)(16,000) = $960,000
The firm should MAKE.
(b) 200,000 + 40Q = 60Q, which results in Q = 10,000
(c) Total cost in (b) = 60Q = 60(10,000) = $600,000
(d) TC for MAKE = FC + VC = 200,000 + (40)(25,000) = $1,200,000
TC for BUY = FC + VC = 0 + 60(25,000) = $1,500,000
The firm should MAKE.

RUBRIC
Total = 10 points.
(a) 1 point each for TC-Make, TC-Buy and for the interpretation of these values. [3]
(b) 1 point for correctly setting up the equation, and 1 point for solving it. [2]
(c) 1 point for correctly setting up the equation, and 1 point for solving it. [2]
(d) 1 point each for TC-Make, TC-Buy and for the interpretation of these values. [3]
-- Minus 0.5 point for each calculation error.

Appendix 3 Final Exam, Open-ended Question, Solution and Rubric

The following table shows the master production schedule for the end-item A:

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>130</td>
</tr>
</tbody>
</table>

Here is the product structure tree:

```
A
  /\        /
C-1 D-2 B-2
  \     /       /
   \   /         /
    \ /          /
     E-3         E-2
```

Here is some data on the items:

<table>
<thead>
<tr>
<th>Item</th>
<th>Lot Sizing Rule</th>
<th>Lead Time</th>
<th>Scheduled Receipts</th>
<th>On-Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Lot for Lot</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Multiples of 60</td>
<td>1</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>C</td>
<td>Lot for Lot</td>
<td>2</td>
<td>40 in period 2</td>
<td>100</td>
</tr>
<tr>
<td>D</td>
<td>Lot for Lot</td>
<td>1</td>
<td>160 in period 2</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Lot for Lot</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Construct a complete material requirements plan for all items. Use the provided MRP tableau.
solutions.

**SOLUTION**

<table>
<thead>
<tr>
<th>Period Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item: A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Requirement</td>
<td>100</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scheduled Receipt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected On-Hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Requirement</td>
<td>100</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned-Order Receipt</td>
<td>100</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned-Order Release</td>
<td>100</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Item: B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Requirement</td>
<td>200</td>
<td>260</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scheduled Receipt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected On-Hand</td>
<td>40</td>
<td>40</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Requirement</td>
<td>200</td>
<td>220</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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Appendix 4 Final Exam, Scaffold EOQ Question, Solution and Rubric

A distributor expects a demand of 5,000 light bulbs over the next year. The administrative cost of processing an order of bulbs is $8. The cost of a bulb is 50 cents, and the cost of carrying a bulb for a year is 20% of the cost of the bulb. The firm operates 300 days a year.

(a) What is the best order quantity of bulbs?
(b) What is the total annual ordering cost incurred by the distributor?
(c) What is the number of order cycles in a year?
(d) What is the length of an order cycle in workdays?
(e) What is the average inventory level of bulbs at any point in time?

SOLUTION

(a) What is the best order quantity of bulbs?
   \[ \text{EOQ} = \sqrt{\frac{2 \times 5000 \times 8}{0.2 \times 0.5}} = 894 \text{ units} \]

(b) What is the total annual ordering cost incurred by the distributor?
   \[ \text{TAOC} = \frac{SD}{Q} = \frac{8 \times 5000}{894} = $44.70 \]

(c) What is the number of order cycles in a year?
   Number of order cycles in a year = \( \frac{D}{Q} = \frac{5000}{894} = 5.59 \) order cycles.

(d) What is the length of an order cycle in workdays?
   Length of an order cycle in workdays = \( \frac{Q}{D} \times 300 = \frac{894}{5000} \times 300 = 53.6 \) days

(e) What is the average inventory level of bulbs at any point in time?
   Average inventory = \( \frac{Q}{2} = \frac{894}{2} = 447 \) units.

RUBRIC

EOQ problem: total 10 points
-- 2 points for each part
-- ½ point for correct formula even if the answer is wrong
-- Minus ½ point for every calculation error
-- 0 points awarded if there is a mistake in either D or Q in part c or d

REFERENCES


