Use of Electronic Spreadsheets to Facilitate Critical Thinking in Quantitative Courses

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ABSTRACT

Electronic spreadsheets such as Microsoft Excel or Lotus can make a valuable contribution in the quantitative courses such as accounting or engineering. These spreadsheets can facilitate critical thinking by eliminating the repetitive calculations associated with scenario analysis. Students can then focus on the applications of managerial decision making or engineering analysis, instead of being overwhelmed by recurring mathematical iterations. It is crucial that the faculty member demonstrate to importance of critical thinking in the quantitative courses.
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Electronic spreadsheets such as Microsoft Excel or Lotus have powerful scenario analysis capabilities that can be used to enhance the critical thinking process for your students. Scenario analysis is important because it helps decision makers to consider all possible outcomes, including the worst case, base, and best case scenarios. Quantifying all benefits and costs is a critical step in the risk management process. The planning process is improved by identifying all potential pitfalls and using all resources available to mitigate these problems.

It is important to perform the calculations manually to develop an understanding of the mechanics involved, but there are little incremental benefits gained by calculating spreadsheet iterations manually, which is necessary for scenario analysis. In the past, scenario analysis was difficult to demonstrate in the classroom because of the amount of tedious mathematical calculations involved. There was a high probability of making a simple math error that would damage the validity of the results. Learning to construct and analyze scenarios is crucial when a final outcome cannot be predicted with a reasonable amount of certainty. Scenario analysis can help the students identify alternatives that they may not think of themselves and it promotes management by exception because it helps identify potential problem areas. Scenario analysis brings realism and pragmatism into the classroom and it presents an essential application that students must be able to effectively utilize to deal with complex situations.

If a scenario were attempted in the classroom, the students would be exhausted by the amount of calculations, they would be too engrossed in the mathematics, and they would not ask the essence of critical thinking: "How do I use these results for managerial decision making or engineering analysis?" Electronic spreadsheets would eliminate the repetitive calculations and allow the students to analyze the results to develop the strategies, processes and tactics to achieve the specified objective.

Use of electronic spreadsheets is also a good way of bringing technology into the classroom and it gives the students an
opportunity to develop an important new computer skill.

**Financial Analysis**

The following spreadsheet is a demonstration of the benefits of the income statement in contribution margin format. A range of revenue alternatives was inserted into the spreadsheet to determine the effect on net income. Total variable costs changed in direct proportion to the changes in units sold in each scenario while total fixed costs remained constant throughout.

<table>
<thead>
<tr>
<th>Total Fixed Costs</th>
<th>$100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Per Unit</td>
<td>$25</td>
</tr>
<tr>
<td>Variable Costs Per Unit</td>
<td>$15</td>
</tr>
<tr>
<td>Units Required to Break-Even</td>
<td>10,000</td>
</tr>
<tr>
<td>Units Sold</td>
<td>10,000</td>
</tr>
<tr>
<td>Total Revenues</td>
<td>$250,000</td>
</tr>
<tr>
<td>Total Variable Costs</td>
<td>150,000</td>
</tr>
<tr>
<td>Total Contribution Margin</td>
<td>100,000</td>
</tr>
<tr>
<td>Total Fixed Costs</td>
<td>100,000</td>
</tr>
<tr>
<td>Net Income</td>
<td>$-</td>
</tr>
<tr>
<td>Contribution Margin per Unit</td>
<td>$10</td>
</tr>
<tr>
<td>Contribution Margin Ratio</td>
<td>40%</td>
</tr>
</tbody>
</table>

The first income statement took about five minutes and was difficult to construct, but the subsequent spreadsheets took less than a minute in total to create. If the scenarios had been calculated manually, these income statements could take about 30 minutes to complete in the classroom. This time is valuable and should be used to discuss the critical thinking process associated with this scenario analysis.

These scenarios indicate the importance of growth in revenues and the corresponding advantages of a greater contribution margin. This spreadsheet would consume valuable time in the classroom if it were constructed manually. Classroom time would be cleared to analyze the results of the scenarios and to discuss the business policy if an electronic spreadsheet was utilized. A paper handout of the spreadsheet would be helpful, but because of its static nature, additional scenarios cannot be analyzed. Fielding questions from the...
students and demonstrating the effects of their requests on an electronic spreadsheet immediately conveys a sense of practicality in the classroom. It helps the students answer for themselves, "How do I use this tool to help me make managerial decisions?" This is the question that initiates the critical thinking process in the students.

Scenario analysis is inherent in financial planning, cost estimating, capital budgeting and valuation models.

**Engineering Analysis**

The following schematic will be used to determine the reliability of the system, which is constructed in a parallel configuration. The elements have a wide range of applications. They could be transistors in electronics, transformers in a power system, or servers in a computer network. The system must meet a minimum level of required reliability, but total costs of the elements must be kept to a minimum.

The more reliable an individual element is, the more expensive it will be. The students can engineer a system that is ultimately reliable, but it would be prohibitively expensive and would violate the least cost criteria. Inexpensive elements could be utilized, but the system would not attain the reliability requirement.

The following calculations and parameters were implemented to construct the schematic:

**Reliability per Element Group:**

\[ 1 - (1 - R(\text{Element}))^n \]

where \( n = \# \) of elements

**System Reliability:**

\[ \prod_{i=1}^{3} R_i \]

Reliability per Element Group

**Constraint:**

\[ 0\% \leq \text{Reliability per Element} \leq 100\% \]
The greater the reliability of the individual element, the greater the system cost; however, elements with lower levels of reliability can be used to achieve the least cost objective but still attain the required system reliability. Students must understand the inverse relationship between element reliability and system cost. If the required reliability for the system is increased, different scenarios could be run in the schematic to determine the reliability of each element necessary to attain system reliability.

The next schematic is a demonstration of reliability scenario analysis. If the required system reliability is 98%, the following configuration can be considered (note the change in the reliability estimates of the individual elements).
To re-engineer the configuration above could take time if done manually, but if the system reliability calculation is done on a spreadsheet, systems analysis can be done quickly and without error. This particular scenario took about 2 minutes to re-engineer and calculate. Students will be able to perform cost/benefit analysis of the different configurations without becoming too involved in the manual calculations. This scenario introduces the importance of critical thinking in engineering analysis, particularly cost/benefit analysis. The system can be engineered to deliver a high level of reliability, but is the high cost justified?

Electronic spreadsheets facilitate critical thinking when this facet of engineering analysis is required. In our analysis, it does not matter if the system configuration is series, parallel, or with standby systems, the spreadsheets will facilitate critical thinking in engineering analysis. It is this type of demonstration that
illuminates the value of electronic spreadsheets in the quantitative courses. Critical thinking then leads to the intuition that is inherent in successful problem solvers.

**Conclusion**

Students must develop the ability to perform risk management and to solve complex problems. Both of these abilities begin with the critical thinking process. In most cases this will involve analyzing various scenarios, interpreting the results and developing the strategies and tactics to achieve the ultimate objective. The difficulty with large-scale problems is that many will require complex, repetitive mathematical calculations to be solved. In advanced courses, these calculations can be time consuming, which would burn valuable time in the classroom, and this time is necessary to help students answer the question “How do I use these results for managerial decision making or engineering analysis?” These repetitive calculations can detract from the main objective of developing strategies and tactics, so electronic spreadsheets should be employed whenever scenario analysis must be performed. These spreadsheets can perform the repetitive calculations and allow the problem solver to allocate time to and to focus on the holistic aspects of the problem. The electronic spreadsheets allow the instructor to facilitate the critical thinking process in the classroom.

Critical thinking, problem solving and risk management must be the main focus of those quantitative courses where the objective is to teach students how to provide a product or service. Electronic spreadsheets are an essential tool in scenario analysis, which is an integral part of the planning process. These spreadsheets allow the instructor to focus on these imperative aspects and to facilitate discussion throughout the course to develop the intuition in problem solvers and decision makers.
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