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Power to business professors:
Automatic grading of problem-solving tasks
in a spreadsheet

**IMPLEMENTATION GUIDE**

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The aim of this guide

In the JAED article, to which this guide forms a supplement, we discuss an application, which enables professors to tailor accounting problem-solving tasks, which are automatically graded to their needs without having to do VBA-coding in Excel. Although the article is based on a specific example, it focuses primarily on outlining key principles and the structure of the general application. The article does not include a detailed guide facilitating implementation of the application. However, this is the purpose of the present document.

Interactive spreadsheet problem-solving tasks can be applied to formative and summative assessments. Assessments that certify achievement use grades as a student’s performance indicator. We call such assessments ‘summative’ or ‘assessment of learning’. On the other hand, assessments may have a formative purpose aiming to modify a learner’s thinking or behavior to improve overall learning. Formative assessments are ‘assessment for learning’.

In this implementation guide, we will first present a tutorial aiming to lower the implementation threshold of the professor. Next, in the reference manual, we will discuss in more detail how professors can tailor different types of problem-solving tasks to their specific needs.

<table>
<thead>
<tr>
<th>What must a professor do to succeed implementing the system on his/her own problem-solving tasks?</th>
<th>What will the professor achieve by implementing the system successfully?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Read in-depth the article <em>Power to Business Professors</em> in <em>Journal of Accounting Education</em>.</td>
<td>1 You will, as a Professor, be released from a lot time consuming (and boring) marking and grading work throughout the whole term.</td>
</tr>
<tr>
<td>2 Work through the tutorial lessons to get familiar with the system.</td>
<td>2 You will engage and motivate your students by providing immediate and constructive feedback both on the students’ problem solving result and on their problem solving process.</td>
</tr>
<tr>
<td>3 Address relevant parts of the reference section.</td>
<td></td>
</tr>
</tbody>
</table>
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Part 1: Tutorial

By going through the tutorial lessons you will be familiar with the user interface of the system, you will learn how to create an interactive problem-solving task and eventually you will be capable of supplementing problem-solving task with multiple-choice questions.
Lesson 1: Become familiar with the user interface

In this lesson you will become familiar with the user interface of an interactive problem-solving task as experienced by a professor when testing an application.

1. Open the file Tutorial_problems.xls and activate the worksheet Problem 1.

In Problem 1 a student is asked to calculate the number of months it will take to achieve a saving goal in B5 based on facts given in A8:C11.

**Using the Retry-button**

The learning outcome for the student may increase if it is not sufficient to simply remember the formulas from the previous attempt, and formulas must be reconstructed at each retry. Thus, repeating the problem-solving task will be more meaningful for the student. When you click Retry, a VBA algorithm generates new facts automatically. The algorithm can also relocate the new facts in the fact range.

1. Click Retry several times to see that random values are entered into random cells in the Facts range.

**Controlling how the Retry-button works**

In the marking sheet, a professor can control how the Retry-button works by entering parameters.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Data generation</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Fact range</td>
<td>B8:C11</td>
</tr>
<tr>
<td>15</td>
<td>Fact orientation</td>
<td>horizontal</td>
</tr>
<tr>
<td>16</td>
<td>Fact randomization</td>
<td>yes</td>
</tr>
</tbody>
</table>

![Fig. 1.1](image)

Fig. 1.1. Facts parameters displayed in the marking sheet.

In Problem 1, the Fact range starts in B8, which is the first cell containing a numeric value, and ends in C11, which is the last cell that can contains a label.

Facts may me oriented horizontal or vertical. When you read row wise, the orientation is horizontal. Else, facts are vertical oriented.
Lesson 1: Become familiar with the user interface

Refresh values only when clicking Retry
When Fact randomization is set to no, facts are not relocated in the fact range. Only the values are updated.

1 Set the Fact randomization parameter to no.
2 Activate the Problem 1 worksheet and click Retry several times to see that only values are refreshed, and that facts are no longer relocated in the Facts range.
3 Return to the Marking 1 sheet and set the Fact randomization parameter to yes.

Understand how random numeric facts are generated
Random numeric facts are retrieved from a normal distribution based on a mean and a standard deviation that you enter into the marking worksheet.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facts</td>
<td>Stocks saving goal</td>
<td>830,000</td>
<td>AVG</td>
<td>SD</td>
</tr>
<tr>
<td>Estimated returns on stocks</td>
<td>9% per month</td>
<td>10%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Stocks market value</td>
<td>450,000</td>
<td>at saving statistics</td>
<td>450,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Monthly savings</td>
<td>3,700</td>
<td></td>
<td>3,500</td>
<td>350</td>
</tr>
</tbody>
</table>

Fig. 1.2. The formula in B8 generates random numbers from a normal distribution.

In the example above, the formula in B8 returns a random value based on the average in D8 and the standard deviation in E8. Finally, the returned value is rounded to the nearest ten thousand by the Round-function (-4).

4 Enter a new average value in D8 in the marking sheet, e.g. 500000.

A new value is generated in B8.

5 Also, enter a new value for standard deviation in E8, e.g. 100000.
6 Press F9 to recalculate and see how the formula in B8 returns new values.
7 Finally, reenter the original values in D8:E8 in the marking sheet (see Fig. 1.2).
**Using the Grade-button**

The solution is graded when you click the Grade-button. If the solution is completely correct or wrong, a message box pop ups and informs you.

1. Click the Grade-button without doing the required calculation in B5 in Problem 1.

   The message box below pops up and informs you.

   ![Feedback](image)

   **Fig. 1.3.** A message box informs about an unsuccessful attempt.

2. Shut the message box, copy the calculation in B5 in the Solution 1 sheet, and paste it into B5 in Problem 1.

3. Click the Grade-button again.

   You have “solved” the problem correct, and the message box informs you about your success.

   ![Feedback](image)

   **Fig. 1.4.** A message box informs about a successful solution.

When you solve a problem only partial correct, the system inserts a separate feedback worksheet as the first sheet in the workbook.

4. Replace the = (equal sign) in front of the formula in B5 in the Problem 1 worksheet with a minus sign, and click Grade.
Lesson 1: Become familiar with the user interface

Fig. 1.5. The system gives feedback on a partial correct solution in a separate worksheet. If you click the hyperlink, you go to the erroneous cell.

A feedback sheet is inserted into the workbook and informs that the sign is wrong.

5. Click the hyperlink in the feedback sheet to go to the cell in the problem worksheet with the error.
6. Point on cell B5 to see the comment informing you about the incorrect sign.

Fig. 1.6. A comment hints on what is wrong with the calculation.

Controlling how the Grade-button works
A professor can control how the Grade button works by specifying grading parameters in the marking worksheet.

Ignoring the sign in a calculation
In the marking sheet, you can specify that a formula result should not be sign sensitive by entering a %-value in the Sign cell. The percentage entered in this cell (D5) determines how much the score is deducted when the sign is wrong.

1. Enter 0 (zero) in D5 in the marking sheet and grade the problem.

Now, the wrong sign is not taken into account and you get a full score.
2 Enter 20% in D5 in the marking sheet and grade the problem again. The new score is 80%. Restore to 50% in D5.

**Scoring individual cell addresses**

If a formula contains multiple cell addresses, the professor may decide that a student should be able to earn points for each relevant address included in the formula. This you can do by setting the Address parameter in C5 to *yes* or *no* in the marking sheet.

1 Delete the reference to the Monthly savings variable in the formula in B5 in the Problem 1 worksheet as shown in the illustration below.

![Fig. 1.7. The reference to Monthly savings is removed from the formula in B5.](image)

2 Grade the problem.

A feedback report explains in plain English which variable is missing in the calculation.

![Fig. 1.8. The feedback report explains which variable is missing.](image)
A professor can require that a formula should be quite correct to give a score by setting the Address parameter in the marking sheet to *no*.

3. Enter *no* in C5 (the Address cell) in the marking sheet, and grade the problem.

A message box informs that your solution is completely wrong.

4. Reset the Address parameter to *yes* in the marking sheet, and grade.
5. Copy the B5 formula in the Solution sheet to B5 in the Problem sheet to restore the correct calculation, and grade.

**Deciding the accuracy of the grading**

You can decide the accuracy of the grading by specifying the Decimals parameter in the marking sheet.

1. Enter +0.1 at the end of the formula in B5 as exemplified below.

   ![Fig. 1.9. There is an error in the B5 formula.](image)

2. Grade the problem.

   A feedback message informs that the calculation is wrong.

3. Go to the marking sheet; enter 0 (zero) in the Decimals cell in E5, and grade.
Now, the message Correct solution displays since the grading is no more sensitive for decimal places.

4 Restore to 3 Decimals in E5 in the marking sheet and grade to control that your score is less than 100%.
5 Remove the error from the formula in B5 in the problem worksheet.

**Scoring the calculation**

If there is only one calculation in a problem-solving task, it should score 100 (percentage). When there are more calculations, you must weigh the scores. This you can achieve by setting Score parameters.

1 Go to the marking sheet, enter **70** in the Score cell in B5, and grade.
2 You receive a score of 70% even if your solution is correct.
3 Restore to **100** in B5 in the marking sheet and grade to control that you now get a full score.
Lesson 2: Creating an interactive problem-solving task

In this lesson, you will create an interactive problem-solving task almost from scratch. That is, your point of departure is a ready-made solution to a problem-solving task. The solution is in a workbook including VBA-modules enabling automatic data generation and grading.

1. Open the file Tutorial_problems.xls and activate the worksheet Solution 2.

This is the solution to problem-solving task where a student shall calculate the true annual interest rate (that is: the internal rate of return) in B4 of an annuity loan based on given facts in A7:C11. To calculate the interest rate, the student is asked first to establish a cash flow model for the loan in B14:B19. Fig. 2.1 illustrates the Solution worksheet we will use in this lesson.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Solution:</strong> Establish the cash flow and calculate the true annual interest rate on an annuity loan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Establish the cash flow to the loan below. Also, calculate the true annual interest rate on the loan.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td><strong>True annual interest rate</strong></td>
<td>5.24%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td><strong>Facts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><strong>Loan amount</strong></td>
<td>118 000</td>
<td>annuity, in arrears</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td><strong>Years to maturity</strong></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td><strong>Instalment charge</strong></td>
<td>570</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td><strong>Number of instalments</strong></td>
<td>1</td>
<td>per year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td><strong>Borrowing rate</strong></td>
<td>4.5%</td>
<td>per year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td><strong>Year</strong></td>
<td><strong>Cash flow</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>118 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>-33 462</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>-33 462</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>-33 462</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>4</td>
<td>-33 462</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2.1. The Solution worksheet we will use in this lesson.

To construct an interactive problem-solving task based on the worksheet in Fig. 2.1, we will continue by creating a corresponding problem worksheet and marking worksheet.
**Prepare the problem worksheet**
You can prepare the problem worksheet by copying the solution sheet, rename the copied sheet, and delete all content that the student shall prepare. Finally, you can copy command buttons into the new problem sheet. Fig. 2.2 illustrates the result.

**Copy the solution sheet and prepare the new problem sheet**
1. Copy the Solution 2 sheet, rename the copy Problem 2, and move it before the Solution 2 sheet.
2. Replace the word Solution in cell A1 in the Problem 2 worksheet with Problem.
3. Delete all content in the Problem 2 sheet that the student shall prepare, which is B5 and B15:B18.

**Copy command buttons to the new problem sheet**
To complete the Problem 2 worksheet, you must copy the two command buttons, which are in the Problem 1 sheet and paste them into the Problem 2 sheet.

1. Activate the Problem 1 worksheet, and right click the Grade button to mark it.
2. Hold down the Shift key and right click Retry to mark this button too.
3. Press Ctrl+c to copy the marked buttons.
4. Activate the Problem 2 worksheet and press Ctrl+v to paste the buttons into this worksheet.
5. Move the buttons to appropriate locations i.e. as in Fig. 2.2
   The command buttons will not work properly until you have prepared the marking sheet.
Lesson 2: Creating an interactive problem-solving task

Prepare the marking worksheet

It is more demanding to prepare the marking worksheet than the problem sheet. In the marking worksheet, we shall insert parameters and formulas needed for automatic data generation and grading. Parameters, we can copy from the Parameters worksheet that is the last worksheet in the tutorial workbook. The formulas we need we can copy from another marking worksheet in the tutorial.

Copy the solution sheet and prepare the new marking sheet

1. Copy the Solution 2 sheet, rename the copy Marking 2, and move it after the Solution 2 sheet.
2. Replace the word Solution in cell A1 in the Problem 2 worksheet with Marking.
3. Delete all content in B5 and B15:B18 in the marking sheet.

Enter formulas that generates randomized facts variates

In the Facts section of the marking sheet, you can specify how randomized data will be generated for each student. As illustrated in Fig. 2.3, random variates are generated for Loan amount (B7) from a normal distribution (NORM.INV) based on a given average (D7) and standard deviation (E7) before finally rounding the returned number (ROUND). In the same way, randomized variates is generated for Instalment
charge (B9:E9), and Borrowing rate (B11:E11). However, for Years to maturity (B8:E8), and Number of instalments (B10:E10), the facts are fixed. Therefore the corresponding AVG and SD cells are empty, and there are no formulas in B8 and B10.

![Fig. 2.3. Formulas generating randomized facts variates.]

To generate a random loan amount, we will copy a similar setup used in the Marking 1 worksheet.

1. Activate the Marking 1 worksheet, select B7:E8, and press Ctrl+c to copy.
2. Activate Marking 2 worksheet, select B6, and press Ctrl+v to paste.
3. In D7:E7 reenter the values displayed in Fig. 2.3.
4. Press F9 several times to calculate new random Loan amounts.

To generate a random Instalment charge, do the following.

1. Copy the formula in B7 to B9.
   #NUM displays in B9 because the formula needs more information to calculate correct.
2. Enter 500 in D9 and 100 in E9 as shown in Fig. 2.3.
   The value 0 displays in B9 because the returned value is rounded to the nearest 10,000.
3. At the end of the formula in B9, replace the parameter -4 with -1.
   The formula is: =ROUND(NORM.INV(RAND(),D9,E9),-1)
   A value is now calculated in B9 and rounded to the nearest 10, e.g. 450.
To generate a random Borrowing rate, you can replicate the above procedure.

1. Copy the formula in B9 to B11.
   Again, #NUM is displayed now in B11.

2. Enter 5% in D11 and 1% in E11 as shown in Fig. 2.3.
   Zero (0) displays in B11 because the returned value is rounded to the nearest 10.

3. At the end of the formula in B11, replace the parameter -1 with 3.
   The formula is: =ROUND(NORM.INV(RAND(),D11,E11),3)

4. For cell B11, select the Percentage format with 1 decimal number.
   A value is calculated in B11 displaying a percentage with one decimal, e.g. 7.3%.

**Specify metadata for the data generation**

In addition to entering formulas to generate randomized variates, you must specify metadata for the Retry button to make it work. The metadata is entered in the marking worksheet, as illustrated in Fig. 2.4. The data-generating algorithm, which is connected to the Retry button, needs to know where the facts are located (Fact range), and their orientation (Fact orientation) whether horizontal (row-wise) or vertical (column-wise). The algorithm must also be informed if the facts should be placed in different cells within the Fact range (Fact randomization) when a student clicks the Retry button.

![Fig. 2.4. Metadata related to the data generation.](image)

To insert metadata parameters for the data generation algorithm, do the following.

1. Activate the Parameters worksheet, select A2:A5, and press Ctrl+c to copy.
2. Activate Marking 2 worksheet, select A25, and press Ctrl +v to paste.
3. In B26:B28 reenter the values displayed in Fig. 2.4.
When you have entered the formulas generating randomized variates and the corresponding metadata, the Retry button will work.

4. Activate the Problem 2 sheet and click Retry to check that randomized data are generated.

*If the Retry button does not work*

If nothing happens when clicking Retry, you must check that the button is assigned to the macro cmdRetry_Click.

![Assigning the Retry button to the cmdRetry_Click macro.](image)

1. Right click the Retry button and select Assign Macro in the short cut menu.
2. Click the macro cmdRetry_click in the dialog box in Fig. 2.5, and click OK.
3. Click the Retry button again.

If the Retry button still does not work, you must make sure that you have set the Data generation parameters correctly (see Fig. 2.4). Having made the Retry button work, we will continue with the Grade button. First we will score the problem-solving task.
**Scoring the problem-solving task**

The calculation in B5 and the cash flow model in B14:B19 (production rules), are scored by specifying four parameters: *Score, Address, Sign*, and *Decimals*.

![Fig. 2.6. Scoring exemplified.]

**Give an overall score to a production rule**

As illustrated in Fig. 2.6, the professor weights the scores in cells B5 and B20 making them add up to 100 points. A student who achieves 100 points has solved the task completely and correctly.

To enter scoring values in the Marking sheet, follow this procedure and have in mind that the result should be equal to that in Fig. 2.6. First, we will score the calculation in B5.

1. Activate the Parameters worksheet, select D3:G4, and press Ctrl+c to copy.
2. Activate the Marking 2 worksheet, select B3, and press Ctrl +v to paste.
3. In B4:E4 enter the values specified in Fig. 2.6.

**Scoring subsets of a production rule**
In addition to scoring every rule, the professor can also score subsets of a production rules individually. In Fig. 2.6, this is accomplished in cells B14:B19. For a given production rule, the sub scores always add up to 100. A negative score indicates that a student has been penalized for undertaking a calculation in a cell that should be left blank (e.g., see cell B19 in Fig. 2.6).

According to cell B20 in Fig. 2.6 the Cash flow entries in B14:B18 gets a maximum score of 80. Each correct cash flow entry adds 20 to the score (20 x 5 = 100). In the cash flow model, no value should be entered for year 5 in B19. If a student does so, he/she will have their score deducted by 30 points. However, the minimum score on a production rule is zero.

We will score the cash flow model using almost the same procedure as above.

1  Activate the Parameters worksheet, select D7:E10, and press Ctrl+c to copy.
2  Activate the Marking 2 worksheet, select A20, and press Ctrl +v to paste.
3  In B20:B23 enter the values specified in Fig. 2.6.

*Enter Address parameters*

If a formula contains multiple cell addresses, the professor may decide that a student should be able to earn points for each relevant address included in the formula. This is accomplished by setting the Address parameter in C4 and B21 of Fig. 2.6 to *yes* or *no*. If set to yes, all addresses in a formula are weighted equally. When the marking algorithm scores the cell addresses used correctly in a formula, a student also earns points if he/she presents a partially correct formula. However, the algorithm does not take into account if operators are applied correctly in a formula.

1  In C4 and B21, enter the values specified in Fig. 2.6.
Lesson 2: Creating an interactive problem-solving task

Enter Sign parameters
The percentage entered into the Sign cells (from 0% to 100%) in D4 and B22 of Fig. 2.6 specifies the score deduction for using a wrong sign in the formula result.

1. In D4 and B22, enter the values specified in Fig. 2.6.

Enter Decimals parameters
If the calculation result is a percentage, the professor can specify how sensitive the marking should be to the number of decimal places entered into the Decimals cells in E4 and B23 of Fig. 2.6.

1. In E4 and B23, enter the values specified in Fig. 2.6.

Enter metadata for grading
Metadata regarding grading is illustrated in Fig 2.7.

![Fig. 2.7. Grading parameters.](image)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Grading</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Calculation range</td>
<td>b4</td>
</tr>
<tr>
<td>31</td>
<td>Model range</td>
<td>a13:b19</td>
</tr>
<tr>
<td>32</td>
<td>Model orientation</td>
<td>vertical</td>
</tr>
<tr>
<td>33</td>
<td>Model axis established by student</td>
<td>no</td>
</tr>
</tbody>
</table>

You can copy the grading parameters from the Parameters worksheet.

1. Activate the Parameters worksheet, select A9:A13, and press Ctrl+c to copy.
2. Activate the Marking 2 worksheet, select A29, and press Ctrl +v to paste.
3. In B30:B33 enter the values specified in Fig. 2.7.
Testing the Grade button

When you have finished the marking sheet, you can test the Grade button.

1. Activate the Problem 2 sheet and click the Grade button.

Now the grading will work if all parameters are entered correctly into the marking sheet. If nothing happens when you click the button, you must assign it to the cmdGrade_Click macro (see Fig. 2.5). If the grading is still wrong, please control all parameters entered.

**TIP 1** The marking sheet contains data necessary for the data generation algorithm and the grading algorithms to accomplish their work. Whenever you reconstruct the problem-solving task, you must update the marking sheet accordingly.

**TIP 2** The file *Tutorial_solutions.xls* includes the solution to Lesson 2.
Lesson 3: Supplementing with multiple-choice questions

The professor can supplement problem-solving tasks with multiple-choice questions or he/she can choose to submit multiple-choice questions only. In this lesson, you will create an interactive multiple-choice task by starting with a ready-made answer key. The answer key is in a workbook including the VBA-modules enabling automatic grading of the questions. Fig. 3.1 exemplifies an answer worksheet.

1. Open the file Tutorial_problems.xls and activate the worksheet Answers.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Question 1: How do you interpret the phrase ‘the time value of money’?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>V</strong></td>
<td>1 dollar today is worth more than one dollar in the future</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><strong>X</strong></td>
<td>1 dollar today is worth less than one dollar in the future</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td><strong>X</strong></td>
<td>1 dollar today is worth as much as one dollar in the future</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td><strong>Question 2: Assume a positive interest rate. Which calculation must we perform to be able to add the amounts in year 0 and year 2 with the year 1 amount in the cash flow below?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>year 0</td>
<td>year 1</td>
<td>year 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td><strong>X</strong></td>
<td>I can simply add the amounts as they are</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td><strong>X</strong></td>
<td>I can calculate the future value in year 1 of the amount in year 0 and the future value in year 1 of the amount in year 2 and then add them up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td><strong>V</strong></td>
<td>I can calculate the present value in year 1 of the amount in year 0 and the future value in year 1 of the amount in year 2 and then add them up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>13</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td><strong>Question 3: Why do we need a cash flow to perform an investment analysis?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td><strong>V</strong></td>
<td>we need a cash flow in order to calculate the present value of a project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td><strong>X</strong></td>
<td>if we have the accounts, we do not need the cash flow of the project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td><strong>V</strong></td>
<td>we need a cash flow in order to take into account the time value of money</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td><strong>X</strong></td>
<td>the cash flow gives us necessary additional information to the project accounts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td><strong>Question 4: Which calculation is made in C26?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Tax rate</td>
<td>28%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Depreciation rate</td>
<td>16%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Required rate of return</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Investment</td>
<td>390 000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Calculation</td>
<td>75 965</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td><strong>V</strong></td>
<td>the present value of tax saved due to depreciation is calculated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td><strong>X</strong></td>
<td>the present value of the investment project is calculated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td><strong>X</strong></td>
<td>the project profit after tax is calculated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td><strong>V</strong></td>
<td>the present value of a growing perpetuity is calculated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3.1. The Answers worksheet.

TIP! In your assignments, you can create your own multiple-choice questions including the answer key (yellow cells in A-column) in the Answers worksheet, and use Format Painter to copy the format of an answer key cell including the drop-down box linked to the cell.
To construct an interactive multiple-choice task based on the worksheet in Fig. 3.1, we will continue to create a corresponding questions and marking worksheet.

**Prepare the Questions worksheet**
You can prepare the question worksheet by copying the answer sheet, rename the copied sheet, and delete all content that the student shall prepare. Finally, you can copy command buttons into the new question sheet just as you did in the previous lesson when you created a problem-solving task. Fig. 3.2 demonstrates the result.

*Copy the answers sheet and prepare the new questions sheet*
1. Copy the Answers sheet, rename the copy Questions, and move it before the Answers sheet.

*Copy command buttons to the new questions sheet*
To complete the Questions worksheet, you must add the two command buttons Retry and Grade.

1. Activate the Problem 1 worksheet, and right click the Grade button to mark it.
2. Hold down the Shift key and right click Retry to mark this button too.
3. Press Ctrl+c to copy the marked buttons.
4. Activate the Questions worksheet and press Ctrl+v to paste the buttons into this worksheet.
5. Move the buttons to appropriate locations i.e. as in Fig. 3.2.

The command buttons will not work properly until you have prepared the marking sheet.
Lesson 3: Supplementing with multiple-choice questions

Fig. 3.2. A question worksheet with two command buttons at the bottom – Grade and Retry.

TIP! When you intend to use multiple-choice questions summative (see Chapter 6), you must not include command buttons in the Question worksheet.
Create and prepare a marking worksheet

It is less demanding to mark multiple-choice questions than problem-solving tasks. In an assignment (workbook), there can be only one questions sheet and accordingly one answer and one marking sheet. You must always name the marking sheet MarkingQst.

Insert a new worksheet in the workbook and name it

1. Insert a new worksheet in the workbook (behind the Answers sheet) and name it MarkingQst.

Now, we shall copy the scoring parameters from the Parameters worksheet.

3. Activate the MarkingQst worksheet, select A1, and press Ctrl+v to paste.

We shall score the questions in the MarkingQst worksheet as illustrated in Fig. 3.3.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Scoring multiple-choice questions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Question</td>
<td>Start Cell</td>
<td>RndRng</td>
<td>Score</td>
<td>Knows Correct</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>a1</td>
<td>a2:a4</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>a6</td>
<td>a10:a13</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>a15</td>
<td>a16:a19</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>a21</td>
<td>a27:a30</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>a32</td>
<td>a33:a36</td>
<td>20</td>
<td>55</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>a38</td>
<td>a39:a43</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Question range</td>
<td>a1:a43</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3.3. A completed MarkingQst worksheet.

Enter stem cells and option ranges

The multiple-choice stems are entered in the start cells (see column B in Fig. 3.3), while the corresponding options are entered in the RndRng cells (column C in Fig. 3.3). More than one correct answer (key) is possible for each stem. When a student clicks Retry, all options are put in random rows in the specified RndRng range.

1. Extend the table as shown in Fig. 3.3.
2. Enter Start cells and RndRng ranges as shown.
Enter scores
In column D in Fig. 3.3, you enter a question’s total score. The key(s) are scored in the column KnowsCorrect (column E in Fig. 3.3), while the distractors are scored in the column KnowsWrong (column F in Fig. 3.3). In the example above, a student earns points also by marking that he/she knows that an item is a distractor.

The sum of the score must always add up to 100. In Question 1 (see Fig. 3.3), there is one key (60) and two distractors (2x20) which equals 100. In Question 3, there are two keys (2 x 35) and two distractors (2 x 15), also adding up to 100.

1 Enter scores as shown in columns D:F in Fig. 3.3.

Enter the Question range
In the question range, you enter the range including data in the answer sheet, i.e. the first row and first column containing data and the last row and last column with data (a1:c43).

1 Enter a question range as in Fig. 3.3.

Testing the multiple-choice application
Finally, you must test your multiple-choice application checking that it works as intended.

1 Control that the Retry button works.
2 Try to answer questions in the question worksheet and click the Grade button.
3 In the Feedback worksheet, check that the questions are graded properly.
4 If the grading is wrong, check carefully that all parameters are entered correctly and grade again.
Part 2: Reference manual

In this reference manual we will discuss preparing of different types of interactive problem-solving tasks. The problem-solving tasks themselves are constructed the same way independent of their purpose except that the two command buttons are not included in the problem worksheets when used summative. Before submitting automatic graded problem-solving tasks for summative use, you should be very familiar with deploying them formatively.

Therefore, Chapter 1 should be your point of departure.
Chapter 1: Point of departure; using problem-solving tasks formatively

When interactive problem-solving tasks are used formatively, students will immediately receive constructive feedback to help them improve their work. This is vital since feedback may induce greater engagement and motivation. When used formatively, the Problem, Solution, and Marking sheets are not separated, but submitted to students in a single workbook, which includes the VBA code modules (see Table 1.1).

Table 1.1
Sequence of events when interactive spreadsheets are used formatively.

<table>
<thead>
<tr>
<th>Individual</th>
<th>Action</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor</td>
<td>Prepares a workbook following the standard procedure described below.</td>
<td>A single workbook can contain several problems. For each problem, there are three worksheets (Problem, Solution, and Marking). The workbook, including all necessary worksheets, is distributed to students via the faculty’s learning management system.</td>
</tr>
<tr>
<td></td>
<td>The solution sheet is hidden while the Marking sheet is set as very hidden. The latter can be accomplished by setting the sheets Visible-property to xlVeryHidden in the VBA editor. Press Alt+F11 to open the editor, click the Solution sheet in the editors Project Explorer, press F4 to display the Properties pane, and select xlVeryHidden as Visible-property.</td>
<td></td>
</tr>
</tbody>
</table>

Student Completes the Problem worksheets and grades them one by one. If the solution is not correct, the student can use the Feedback worksheet and the Solution worksheet (which must first be made visible) to track and correct errors.

Step 1: Save the workbook file ‘Automatic formative grading of problem-solving tasks’ with a new file name and use the new file as a template

The workbook Automatic formative grading of problem-solving tasks is a good starting point for creating problem-solving tasks, which are designed to be used
formatively. Save the file with a new file name. It may be helpful to associate the file name with a corresponding course number and the assignment date (yymmdd), e.g. FIN_2020_Practicing_140215

Additionally, for creating problem-solving tasks associated with a text book, it may be a good idea to associate the file name with the corresponding book chapter, e.g.

Chap 01_Calculating future values

**Step 2: Delete worksheets not needed for the specific assignment**

Assume you have saved the workbook file *Automatic formative grading problem-solving tasks* with the new filename FIN_2020_Practicing_140215. In this workbook, you will find worksheet templates for different types of problem-solving tasks and multiple-choice questions as well. You should now delete all worksheets not needed for your specific assignment.

Imagine you intend to use only multiple-choice questions and a goal-seeking problem-solving task. If so, you must keep the worksheets Questions, Answers and MarkingQst for the multiple-choice questions, and accordingly the Problem, Solution and Marking worksheets for the goal-seeking problem-solving task. The other worksheets in the workbook are irrelevant for this assignment and should be deleted.

1. Delete all worksheets not needed for this specific assignment.

After having deleted the unnecessary worksheets, the workbook contains only the worksheets you (and your students) will use and the hidden VBA-modules needed to grade the students work (when a student clicks the Retry-button or the Grade-button, the code will automatically execute behind the ‘scene’).

For cosmetic reasons, you may prefer to rename the worksheets containing the problem-solving tasks, e.g. from Problem 4, Solution 4 and Marking 4 to Problem 1, Solution 1 and Marking 4.

2. Rename the worksheets if you like.
In a workbook, you can only have one worksheet with multiple-choice questions and corresponding sheets with answers and marking information. Accordingly, these worksheets should keep their names.

**Step 3: Clear all existing data in the Problem and Solution worksheets**
Before starting developing your own problem-solving task, you must clear all data in the Solution and Problem worksheets you intend to use as follows:

1. Click the Solution worksheet and press Ctrl+a to select all.
2. On the Home tab, in the Editing group, click the arrow next to the Clear button.
3. Click Clear All to clear all content, formatting, and comments in the worksheet.
4. Use procedures 1–3 above to clear all data in the Problem worksheet as well.

As a result of this step, all the data is cleared in the Problem worksheet except for the command buttons. A command button can be moved by right clicking a button and dragging it to a new location.

**Step 4: Build a new problem-solving task**
After having cleared all data from the Solution and Problem worksheets, you can construct a new problem-solving task in the Solution worksheet. After having completed the Solution worksheet, continue by copying its content to the Problem worksheet in the manner described as follows.

1. Select all in the Solution worksheet, copy, and paste it into the Problem worksheet.
2. In the Problem sheet, delete all content that a student is required to create himself.
3. Move the two command buttons to appropriate positions on the Problem worksheet.

**Step 5: Reset parameters in the Marking worksheet and provide scores**
When the Problem and Solution worksheets are completed, the Marking worksheet remains to be prepared. The Marking worksheet contains data necessary to generate randomized facts and to score and grade the problem-solving task.
**TIP!** To obtain correct facts and scoring, the information in this worksheet must be very accurate.

All parameters must be reset, and each element in the solution must be scored by entering a *Score*, each *Address* in a formula must be specified whether or not it should be evaluated, the importance of the *Sign* of the calculations must be indicated, and, finally, the number of *Decimals* in the calculations must be set.

In Chapter 2, a goal-seeking problem-solving task is marked. If you are creating a modeling problem-solving task, read Chapter 3. For more (and simpler) examples of marking modeling problem-solving tasks, review Marking 1, Marking 2, and Marking 3 in the workbook *Automatic summative grading of problem-solving tasks*. In Chapter 4, we discuss marking of a regression problem-solving task. In Chapter 5, we have described marking an optimization problem-solving task while multiple-choice questions are marked in Lesson 3.

**TIP 1** Whenever you reconstruct the problem-solving task, you must update the marking sheet accordingly.

**Step 6: Hide worksheets**

Before deploying interactive problem-solving tasks to you students, you should hide the solution worksheets and very hide the marking worksheet. By hiding the solution worksheet, it may not become too tempting for your students to look at this as they try to solve the problem on their own. The marking worksheet is a tool for the professor only, and should not be available to students.

1. Hide the solution worksheet. A student can unhide it when he/she wants to.

You can set the marking sheet to very hidden by setting the sheets Visible-property to *xlVeryHidden* in the VBA editor.

2. Press Alt+F11 to open the editor, click the marking sheet in the editors Project Explorer, press F4 to display the Properties pane, and select *xlVeryHidden* as Visible-property. You can repeat the procedure above to unhide the marking sheet.
Chapter 2: Creating a goal-seeking problem-solving tasks

In the workbook *Automatic formative grading of problem-solving task*, you will find an example of a goal-seeking problem. Fig. 2.1 illustrates the solution worksheet of the example, which calculates the break-even point in units based on some given facts.

![Fig. 2.1. The solution worksheet of the goal-seeking problem-solving task exemplified in the workbook Automatic formative grading of problem-solving task.](image)

### Prepare the solution and problem worksheets to a goal-seeking problem-solving task

Create your own solution worksheet and problem worksheet to a goal-seeking problem-solving task based on the template in the workbook *Automatic formative grading of problem-solving task*. You can follow the procedure outlined in Chapter 1.
Prepare the marking worksheet

After having prepared the solution worksheet and the problem worksheet of the problem-solving task by following the general procedure discussed in Chapter 1, you can score and grade the goal-seeking problem.

Step 1: Generate random facts
In the Facts section of the marking sheet, you can specify how individualized data is produced for each student. As illustrated in Fig. 2.2, random variates are generated for Fixed costs (B5) from a normal distribution (NORM.INV) based on a given mean (like the value given in cell E5) and standard deviation (in F5) before finally rounding the returned number (ROUND). In the same way, individualized data is generated for the other Facts variables (see B7:B8, C9:C10, and D11:D12).

![Fig. 2.2. Random facts to the goal-seeking problem-solving task in Fig 2.1.](image)

Step 2: Specify metadata to the facts generation
Metadata regarding individualized data generation is entered into the marking worksheet, as illustrated in Fig. 2.3. The data-generating algorithm needs to know where the facts are located. In Lesson 2, we discuss this issue thoroughly.

![Fig. 2.3. Metadata related to the data generation of the goal-seeking problem-solving task in Fig. 2.1.](image)
Chapter 2: Creating a goal-seeking problem-solving tasks

Step 3: Enter grading parameters
In Fig. 2.4, the grading parameters for the goal-seeking problem-solving task displayed in Fig. 2.1 are entered. The labels in A31:A34 can be copied from the parameters worksheet.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>30</td>
<td>Grading Goal Seek</td>
</tr>
<tr>
<td>31</td>
<td>Calculation range</td>
</tr>
<tr>
<td>32</td>
<td>Goal seek: Set cell</td>
</tr>
<tr>
<td>33</td>
<td>Goal seek: To value</td>
</tr>
<tr>
<td>34</td>
<td>Goal seek: Changing cell</td>
</tr>
</tbody>
</table>

**Fig. 2.4.** Grading parameters to the goal-seeking problem-solving task in Fig 2.1.

First, we enter the two calculation ranges involved. Thereafter we enter the three parameters being specific for a goal-seeking problem-solving task: Set cell, To value, and Changing cell.

Step 4: Enter scoring parameters
In Fig. 2.5, the goal-seeking problem-solving task is scored.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>15</td>
<td>Calculations</td>
<td>Score</td>
</tr>
<tr>
<td>16</td>
<td>Revenue</td>
<td>10</td>
</tr>
<tr>
<td>17</td>
<td>Variable unit costs</td>
<td>10</td>
</tr>
<tr>
<td>18</td>
<td>Setup costs</td>
<td>25</td>
</tr>
<tr>
<td>19</td>
<td>Inspection costs</td>
<td>25</td>
</tr>
<tr>
<td>20</td>
<td>Fixed cost</td>
<td>10</td>
</tr>
<tr>
<td>21</td>
<td>Operating income</td>
<td>10</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Question</td>
<td>Score</td>
</tr>
<tr>
<td>24</td>
<td>BEP in units</td>
<td>10</td>
</tr>
</tbody>
</table>

**Fig. 2.5.** Scoring of the goal-seeking problem-solving task displayed in Fig. 2.1.

Where the Address parameter is set to yes, also the cell addresses in the formulas will be scored.
Chapter 3: Creating a modeling problem-solving task

When a student implements a model, that student must create multiple calculation procedures in a structure established by the student. The example described in the JAED article is a typical modeling problem, and the original article should be consulted when implementing this kind of problem-solving task. In this implementation guide, we will discuss only the elements not outlined in the article due to space constraints.

Prepare the solution and problem worksheets of a modeling problem-solving task

Create your own solution worksheet and problem worksheet to a modeling problem-solving task based on the template in the workbook Automatic formative grading of problem-solving task. You can follow the procedure outlined in Chapter 1.

Provide labels in a data list

To enable automatic grading, the model labels can be predefined and presented in a data list to prevent typing errors from students. A data list can be created by the data validation function in Excel. In the JAED article, for example, when a student clicks B7 or A19:A26 (see Fig. 4 in the article), a dropdown arrow is displayed as in Fig. 3.1 below.

![Fig. 3.1. The dropdown arrow attached to a data list.](image)

When clicking the arrow, like that shown in Fig. 3.1, a data list opens with available options, as illustrated in Fig. 3.2. In the list, there may also be distractor labels that require the student to evaluate if a label is valid in the given model or not.
Chapter 3: Creating a modeling problem-solving task

Fig. 3.2. A data list including distractor labels (Depreciation and Sales Revenue).

**Step 1: Type the list entries in the worksheet**

It is wise to create the data list in the solution worksheet, because, afterwards it can be copied to the problem worksheet. The list entries should be inserted outside of the working screen so as not to disturb the student when solving the problem (see Fig. 3.3).

![Fig. 3.3. The entries to a data list in the solution worksheet.](image)

**Step 2: Create the list**

To create a Data List, click Data in the main menu, open the Data Validation drop down menu, and select Data Validation, as illustrated in Fig. 3.4.

![Fig. 3.4. Data Validation.](image)
Finally, you can select List and specify the Source of the list in the dialog shown in Fig. 3.5.

![Data Validation Dialog](image)

**Fig. 3.5.** The List option is selected and a Source range is entered.

**Prepare the marking worksheet**

After having prepared the solution worksheet and the problem worksheet of the modeling problem-solving task by following the general procedure discussed in Chapter 1, and the specific steps above, you can score and grade the problem.

**Step 1: Generate random facts**

Students work with individualized data sets based on values chosen from a normal distribution as explained below.

![Data Table](image)

**Fig. 3.6.** Choosing a random value from a normal distribution and rounding it.

As illustrated in Fig. 3.6, the Investment value in cell B10 is chosen randomly from a normal distribution based on the average value entered the in cell D10 and the standard deviation in E10. This function is described in detail as follows:
- the NORM.INV-function returns a random variates from a normal distribution with a specified mean and standard deviation;
- the RAND-function selects a random value from the normal distribution;
- the ROUND-function rounds the value returned, in this example (-5) to the nearest 100 000.

The formula in cell B10 is copied to cells B11:B12 to also fill these cells with random numbers chosen from their corresponding normal distribution. The formula in cell B11 rounds the returned value to the nearest 10 000 by supplying the Round-function with a value of -4: =ROUND(NORM.INV(RAND(),D11,E11),-4)

In this example, the Tax Rate (B13) is fixed (28%). The Declining Balance Depreciation Rate and the Required Rate of Return are, however, retrieved from a normal distribution, e.g., in cell B14: =ROUND(NORM.INV(RAND(),D14,E14),2)

**Step 2: Specify metadata to the facts**

Metadata regarding individualized data generation is entered into the marking worksheet, as illustrated in Fig. 3.7. The data-generating algorithm needs to know where the facts are located. In Lesson 2, we discuss this issue thoroughly.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Data generation</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Fact range</td>
<td>b10:c15</td>
</tr>
<tr>
<td>30</td>
<td>Fact orientation</td>
<td>horizontal</td>
</tr>
<tr>
<td>31</td>
<td>Fact randomization</td>
<td>yes</td>
</tr>
</tbody>
</table>

**Fig. 3.7.** Metadata regarding facts.

**Step 3: Enter grading parameters**

Metadata regarding grading is in the marking worksheet, as illustrated in Fig. 3.8.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Grading</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Model range</td>
<td>a18:g26</td>
</tr>
<tr>
<td>34</td>
<td>Model orientation</td>
<td>horizontal</td>
</tr>
<tr>
<td>35</td>
<td>Model axis established by student</td>
<td>yes</td>
</tr>
<tr>
<td>36</td>
<td>Calculation range</td>
<td>b6</td>
</tr>
<tr>
<td>37</td>
<td>Decision range</td>
<td>b7</td>
</tr>
<tr>
<td>38</td>
<td>IF formula with decision logic</td>
<td>yes</td>
</tr>
</tbody>
</table>

**Fig. 3.8.** Metadata regarding grading.
First, the Model range parameter is specified. Next, the Model orientation parameter is entered as horizontal or vertical. Moreover, you specify if the student establishes the model’s main axis or not. The Calculation range parameter contains a decision critical calculation (which, in the JAED example, was the net present value). The Decision range is where a student enters his/her decision. The decision outcome will depend on the result located in the Calculation range. Since the students receive an individualized data set, their solution must be tailored accordingly. In the example above, this is accomplished by an IF-formula located in another cell having the following decision logic:  

$$\text{=IF}(B6\geq 0, \text{"yes"}, \text{"no"})$$

**Step 4: Enter scoring parameters**

Model entries, decision critical calculations, and final decisions are scored by specifying four parameters: *Score, Address, Sign, and Decimals.*

![Fig. 3.9. Scoring a modeling problem-solving task.](image)

Give an overall score to a production rule

As illustrated in Fig. 3.9, the professor weights the production rules in cells B6:B7 and H19:H26. A student who achieves 100 points has solved the task completely and correctly.
Scoring subsets of a production rule

In addition to scoring every rule, the professor can also score subsets of the production rules individually. In Fig. 3.9, this is accomplished in cells B19:G26. For a given production rule, the sub scores always add up to 100. A negative score indicates that a student has been penalized for undertaking a calculation in a cell that should be left blank (e.g., see ranges C19:F19, B20:B21, C22:G23 in Fig. 3.9).

Fig. 3.9 shows that the Investment and Disinvestment entry in cell A19 gets a maximum score of 10 points and that 50% of this score is earned by entering the investment (in cell B19) and the other 50% by entering the disinvestment (cell G19). For this item, no value should be entered for the cash amount in the cells for Project Cash Flow in Years 1-4. If a student does so, he/she will have their score deducted by 25 points. However, the minimum score on a production rule is zero.

Scoring irrelevant production rules

In Fig. 3.9, Depreciation and Sales Revenue (rows 24:25) are irrelevant entries since this is a cash flow model. This fact is marked in two ways: first, these labels are entered in a red font, and, next, there are no sub scores assigned to these labels, only a main score. In this example, if a student omits an irrelevant item in his/her model, the student will earn 10 points, and, if an irrelevant production rule is included, these points will not be earned. For the marking code to detect irrelevant items, it is crucial that the red font color is selected for these labels in the marking worksheet.

Scoring a partially correct formula

If a formula contains multiple cell addresses, the professor may decide that a student should be able to earn points for each relevant address included in the formula. This is accomplished by setting the Address parameter C6, I19:I23, and I26 of Fig. 3.9 to yes or no. All addresses in a formula are then weighted equally. When the marking algorithm scores the cell addresses used correctly in a formula, a student also earns points if he/she presents a partially correct formula. However, the algorithm does not take into account if operators are applied correctly in a formula. The percentage entered into the Sign cells (from 0% to 100%) in D6, J19:J23, and J26 of Fig. 3.9 specifies the score deduction for using a wrong sign in the formula result.
Specifying how sensitive the marking should be to the number of decimal places
If the calculation result is a percentage, the professor specifies how sensitive the marking should be to the number of decimal places entered into the Decimals cells in E6, K19:K23, and K26 of Fig. 3.9.

Supplying the Feedback report using the specified labels
The text entered into the cells of the A-column in the model range of the marking worksheet, as shown in Fig. 3.9, are used by the Feedback report.

Is the order of the entered production rules important?
The scoring does not depend on which row a student has entered his/her item in the Problem worksheet. Any of the cells in the range A19:A26 are valid for model entries.
Chapter 4: Creating an optimization problem-solving task

After installing the Solver add-in, the Solver can be used to solve optimization problem-solving tasks. Fig. 4.1 illustrates the solution worksheet to the regression problem-solving task included in the workbook *Automatic formative grading of problem-solving task*.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solution: Deciding product mix to maximize profit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Quality Shirts Industries manufactures four varieties of ties. One is an expensive, all-silk shirt, one is an all-polyester shirt, and two are blends of polyester and cotton. Based on the facts below, you are asked to decide the product mix in order to maximize profit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Max Profit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>137,541</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Number of units</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>All silk</td>
<td>All poly</td>
<td>Blend-1</td>
<td>Blend-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Selling price</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Labor cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Material cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Profit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Constraints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Constr. LHS</td>
<td>Sign</td>
<td>Constr. RHS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Yards of silk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Yards of polyester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Yards of cotton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Maximum all silk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Maximum all poly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Maximum blend-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Maximum blend-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Minimum all silk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Minimum all poly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Minimum blend-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Minimum blend-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7,500</td>
<td>12,101</td>
<td>14,119</td>
<td>8,200</td>
<td></td>
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<td></td>
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<tr>
<td>2</td>
<td>8.37</td>
<td>3.84</td>
<td>4.52</td>
<td>5.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.69</td>
<td>0.69</td>
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<td>4</td>
<td>2.93</td>
<td>0.54</td>
<td>0.86</td>
<td>0.97</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>4.75</td>
<td>2.61</td>
<td>2.97</td>
<td>3.46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.118</td>
<td>0.08</td>
<td>0.052</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.048</td>
<td>0.031</td>
<td>0.069</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1,900</td>
<td>&lt;=</td>
<td>1,300</td>
<td>&lt;=</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td>7,500</td>
<td>&lt;=</td>
<td>12,101</td>
<td>&lt;=</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>14,119</td>
<td>&lt;=</td>
<td>8,200</td>
<td>&lt;=</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>8,200</td>
<td>&lt;=</td>
<td>12,101</td>
<td>&lt;=</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>8,200</td>
<td>&lt;=</td>
<td>7,500</td>
<td>&lt;=</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>885</td>
<td>&lt;=</td>
<td>1,000</td>
<td>&lt;=</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 4.1.** Solution worksheet to an optimization problem-solving task exemplified.

The purpose of the optimization illustrated in Fig. 4.1 is to estimate the number of units of four different products produced (in categories given as All silk, All poly, Blend-1 and Blend-2 in cells B8:E8) to maximize profit (B5). Selling prices, Labor costs, Material costs, and Profits are given in cells B9:E12, and represent the Constraints given in cells B15:H25.
Prepare the solution and problem worksheets of an optimization problem-solving tasks

Create your own solution worksheet and problem worksheet to an optimization problem-solving task based on the template in the workbook *Automatic formative grading of problem-solving task*. You can follow the procedure outlined in Chapter 1.

Prepare the marking worksheet

After having prepared the solution worksheet and the problem worksheet of the optimization problem-solving task, you must generate random facts, and score and grade the task using the marking worksheet.

**Step 1: Specify metadata to the facts generation**

Fig. 4.2 displays parameters specifying metadata to the optimization problem in Fig. 4.1.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Data generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Fact range</td>
<td>B9:E11, B15:E17, H15:H25</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Fact orientation</td>
<td>horizontal, horizontal, vertical</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Fact randomization</td>
<td>no, no, no</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Output condition range</td>
<td>B37:B38</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 4.2.** Metadata relevant to the optimization problem-solving task in Fig. 4.1.

Individualized facts are generated in B9:E11, B15:E17, and H15:H25 as specified in the marking sheet. These data are copied by the VBA code to the related ranges in the problem and solution worksheets when a student clicks the Retry command button. The two first ranges in this example are orientated horizontally, while the last range is vertical (see Fact orientation in B42 in Fig. 4.2).
Step 1: Generate Selling price, Labor cost, Material cost, and Profit

The selling price for All silk is generated in cell B9, as illustrated in Fig. 4.3. A random number is chosen from a normal distribution and rounded it to two decimal places. The number selected is based on the average given in cell B28 and the standard deviation in C28. Selling prices for the three other products are generated accordingly in cells C9:E9.

![Fig. 4.3. Random Selling price, Labor cost, Material cost, and Profit is chosen from a Normal distribution.](image)

For All silk, the Labor cost given in cell B10 is generated in the same way as was the Selling price. In the example, for the three other products, labor cost is equal to the labor cost for All silk. Material costs in cells B11:E11 are calculated as different percentages of the corresponding selling prices. Profits, as given in cells B12:E12, are calculated as the Selling price less Labor cost, and Material cost.

The constraints for Yards of silk and Yards of polyester in cells B15:E16 (see Fig. 4.1) are generated as above. Yards of cotton given in cell D17 is, however, calculated as 0,1-D16. So is Yards of cotton calculated in E17.

In addition, the right hand side constraints are chosen randomly from a normal distribution, as shown in Fig. 4.4.
Step 2: Setting output conditions
The output conditions specified in cells B37:B38 of Fig. 4.5 ensure that the Blend-1 Selling price and Material cost is always larger than that of Blend-2.

Step 3: Grade and score an optimization problem-solving task
In Fig. 4.6, the grading and scoring parameters for the optimization problem-solving task are shown.
In addition to scoring the production rules (see Fig. 4.6), sub scores are entered in the optimization model as illustrated in Fig. 4.7 and 4.8.

**Fig. 4.7.** Scoring the objective (B5) and the decisions (B8:E8) in the optimization problem-solving task exemplified in Fig. 4.1.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Max Profit</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Number of units</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>All silk</td>
<td>All poly</td>
<td>Blend-1</td>
<td>Blend-2</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 4.8.** Scoring the constraints (B18:E18, F15:F25) in the optimization problem-solving task exemplified in Fig. 4.1.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Constr. LHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Constraints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Yards of silk</td>
<td>0.109</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Yards of polyester</td>
<td>0.081</td>
<td>0.055</td>
<td>0.035</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Yards of cotton</td>
<td></td>
<td>0.045</td>
<td>0.065</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Constraint: Maximum all silk</td>
<td>13</td>
<td>-4</td>
<td>-4</td>
<td>-4</td>
<td>9</td>
</tr>
<tr>
<td>19</td>
<td>Constraint: Maximum all poly</td>
<td>-4</td>
<td>13</td>
<td>-4</td>
<td>-4</td>
<td>9</td>
</tr>
<tr>
<td>20</td>
<td>Constraint: Maximum blend-1</td>
<td>-4</td>
<td>-4</td>
<td>13</td>
<td>-4</td>
<td>9</td>
</tr>
<tr>
<td>21</td>
<td>Constraint: Maximum blend-2</td>
<td>-4</td>
<td>-4</td>
<td>-4</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>22</td>
<td>Constraint: Minimum all silk</td>
<td>13</td>
<td>-4</td>
<td>-4</td>
<td>-4</td>
<td>9</td>
</tr>
<tr>
<td>23</td>
<td>Constraint: Minimum all poly</td>
<td>-4</td>
<td>13</td>
<td>-4</td>
<td>-4</td>
<td>9</td>
</tr>
<tr>
<td>24</td>
<td>Constraint: Minimum blend-1</td>
<td>-4</td>
<td>-4</td>
<td>13</td>
<td>-4</td>
<td>9</td>
</tr>
<tr>
<td>25</td>
<td>Constraint: Minimum blend-2</td>
<td>-4</td>
<td>-4</td>
<td>-4</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>
Chapter 5: Creating a regression problem-solving task

Regression is the most demanding problem-solving task to implement. It requires that the professor be familiar with array formulas and the LINEST function in Excel. Fig. 5.1 illustrates the solution worksheet to the regression problem-solving task included in the workbook *Automatic formative grading of problem-solving task*.

![Fig. 5.1. The solution worksheet to a regression problem-solving task exemplified.](image)

The purpose of the regression problem illustrated in Fig. 5.1 is to estimate the costs of painting a house (the dependent variable) with respect to given number of Square Feet (D27) and Openings (F27), which are the two cost drivers. To estimate the regression coefficients, the three regression models use the LINEST function entered as array formulas (Ctrl+Shift+Enter) in cells B30:D34, F30:G34, and I30:J34.
**Prepare the solution and problem worksheets of a regression problem-solving task**

Create your own solution worksheet and problem worksheet to a regression problem-solving task based on the template in the workbook *Automatic formative grading of problem-solving task*. You can follow the procedure outlined in Chapter 1.

**Prepare the marking worksheet**

After having prepared the solution worksheet and the problem worksheet of the regression problem-solving task, you must generate random facts, and score and grade the task using the marking worksheet.

**Step 1: Specify metadata to the facts generation**

Fig. 5.2 displays parameters specifying metadata applicable to the regression problem. The labels in column A are copied from the Parameters worksheet.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>Data generation</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Fact range</td>
<td>b11:d22</td>
</tr>
<tr>
<td>39</td>
<td>Fact orientation</td>
<td>vertical</td>
</tr>
<tr>
<td>40</td>
<td>Fact randomization</td>
<td>no</td>
</tr>
<tr>
<td>41</td>
<td>Output condition range</td>
<td>k20:k22</td>
</tr>
<tr>
<td>42</td>
<td>Simulation range</td>
<td>d27:f27</td>
</tr>
<tr>
<td>43</td>
<td>Number of possible answers</td>
<td>4</td>
</tr>
</tbody>
</table>

**Fig. 5.2.** Metadata relevant to the data generation of the regression problem-solving task in Fig. 5.1.

In the following, we will discuss each parameter specified.

**Step 2: Generate random facts based on the user-defines Cholesky function**

Individualized facts are generated in cells B11:D22 in the marking worksheet, illustrated in Fig. 5.3. In the example, data is generated for the three variables Square Feet, Openings, and Cost based on their Mean, and given that the returned data complies with the conditions set in K20:K23 which requires that the fixed and variable costs per unit must be positive. Moreover the model choice must be one of four possible outcomes of this regression.
Fig. 5.3. The user defined Cholesky function generates multivariate normal random numbers using Cholesky’s algorithm.

The function Cholesky generates multivariate normal random numbers using Cholesky’s algorithm. The user defined function is implemented as an array formula in cells B11:D11, and then copied to B12:D22. In the following example, the INT function converts the returned values to an integer:

\[ \{=\text{INT}(\text{cholesky}(G11:I11))\} \]

Cholesky requires one argument: the means as specified in G11:I11 in Fig. 5.3. Moreover it uses a default standard deviation (10% of the mean), and a default correlation coefficient (95%).

**Step 3: Specify output conditions**

The condition construct ensures that the returned data complies with conditions set in the Output condition range found in cells K20:K23 in this example (see Fig. 5.4). In the Output condition range, output criteria are entered. New input data will be generated until all conditions are met by the returned regression solution.

Fig. 5.4. Output conditions.
Fixed and Variable costs per unit must be positive numbers in the solution. The array formula given in cell K20: `{=AND(G20:I20>0)}` of Fig. 5.4 requires fixed cost to always be a positive number. In cells G20:I20, fixed costs are retrieved from the three current regression models located in the Solution worksheet, where, for example, cell G20 is linked to `='Solution 4'!D30` in which the fixed cost given by Regression model 1 is calculated. Similar formulas will be found in cells H20 and I20 of Fig. 5.4 linking the fixed cost to the two other regression models. All together, the criterion in cell K20 requires fixed cost to be positive in all three regression models. Accordingly, also VC (variable costs) per unit must be positive. This is accomplished by the criterion given in cell K21 and the related linked formulas in cells G21:I21.

The Model choice condition given in K22 of Fig. 5.4 secures, together with the Number of possible answers parameter in cell B43 in Fig. 5.2, that one of the four possible answers to this specific regression problem-solving task is chosen randomly, thus preventing one solution to be over-represented.

Depending on the t-values illustrated in row 35 of Fig. 5.1, the cost drivers may be retrieved from Regression models 1, 2, or 3, or both cost drivers may be statistically insignificant. If so, new cost drivers must be sought. The VBA code uses the parameter entered in Number of possible answers located in cell B43 of Fig. 5.2 to select one of the four possible alternatives randomly.

The value located in cell B43, which the code will change during data generation and then reset, is used by the Model choice condition of cell K23 shown in Fig. 5.5 to secure that the t-values returned correspond to the model number which the VBA code will insert in cell B43. This is accomplished by the IF-statement shown in Fig. 5.5, which is entered as an array formula in cell K23.

<table>
<thead>
<tr>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>22</td>
</tr>
</tbody>
</table>

**Fig. 5.5.** The Model choice condition entered as an array formula.
Step 4: Specifying simulation values

The Simulation range (see B42 in Fig. 5.2) specifies where random numbers used in a problem-solving task are located. When estimating the cost of painting a house (see cell A27 in Fig. 5.1), the number of square feet (D27) and number of Openings (F27) are generated randomly for each student. In D27, the RANDBETWEEN function returns a number between 1800 and 2300 (=RANDBETWEEN(1800,2300)). A similar calculation returns between 8 and 12 openings in F27.

Step 5: Enter grading parameters

Fig. 5.6 illustrates the metadata regarding grading parameters for the regression problem-solving task in Fig. 5.1.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>Grading Regression</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Question range</td>
<td>A24:A26, H27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Array model range</td>
<td>B30:B34, F30:F34, I30:I34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>t-values range</td>
<td>B35:B35, F35:F35, I35:I35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Array orientation</td>
<td>vertical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Array heading text</td>
<td>Regression 1: Openings, Square Feet, Fixed Cost; Regression 2: Square Feet, Fixed Cost; Regression 3: Openings, Fixed Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Array formula range</td>
<td>A24:A26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Array formulas</td>
<td>=IF(AND(B35:C35&gt;2),C30,IF(C35&gt;2,F30,0))=IF(AND(B35:C35&gt;2),B30,IF(B35&gt;2,I30,0))=IF(AND(B35:C35&gt;2),D30,IF(AND(B35:C35&lt;2),0,IF(B35&gt;2,J30,G30)))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Decision formula range</td>
<td>H27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Decision formula</td>
<td>=IF(AND(B35:C35&gt;2),H27)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>Decision formula text</td>
<td>Both cost drivers are statistically insignificant and we need to look for new cost drivers.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5.6. Metadata regarding grading of a regression problem-solving task exemplified in Fig. 5.1.

In this example there are two Question ranges separated by a comma (E24:E26, H27), and three Array model ranges that provides an Array model for each regression model (B30:D34, F30:G34, I30:J34). In addition, the t-values for each regression model are given in three ranges (B35:D35, F35:G35, I35:J35).

The Array orientation is vertical. The Array heading texts are used in the Feedback report, one text for each array. The Array formulas are entered as a long string in cell B51 with an ‘=’ sign separating the formulas. The VBA code will insert the Array formulas in cell B51 into the Array formula range (E24:E26). The appropriate formula is placed into the correct cell in the solution worksheet when the user clicks the Retry-button. To track consecutive errors, the array formulas are inserted into the same cells when the problem is graded.
In the Decision formula range given in cell B52 of Fig. 5.6 (H27), the corresponding decision formula (see cell B53) is inserted. The Decision formula text is entered into cell B54. This text is displayed in the Decision formula range when none of the models return significant regression results. The calculation ranges are in cells B35:C35, F35, I35, and H27.

Step 6: Scoring a regression problem-solving task

The total score a student can achieve is 100. By answering the three questions in cells A14:A26, a student reveals whether he/she selects data from the significant regression model. The student earns 14 points for answering each of the questions correct, as illustrated in cells E24:E26 in Fig. 5.7.

By answering Question 4 (Q4) in cell H27 (see Fig. 5.7), a student demonstrates that he/she can use the data to estimate the cost of painting a house for specified numbers of Square Feet and Openings. For this calculation, a student earns a score of 22. A student earns the remaining scores by implementing the 3 regression models correctly (see B30, F30, and I30 in Fig. 5.7) and by calculating the corresponding t-values.

As the regression calculations are implemented by array formulas, each model is scored as a unit and not cell by cell.

![Fig. 5.7. Scoring a regression problem-solving task.](image-url)
Chapter 6: Ending point; using problem-solving tasks

**summative**

When automatic graded problem-solving tasks are used for assignments and exams (summative assessments), the professor and students will follow the sequence of events explained in Table 6.1.

### Table 6.1.
Sequence of events when interactive problem-solving tasks are used summative.

<table>
<thead>
<tr>
<th>Individual</th>
<th>Action</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor</td>
<td>Prepares the problem-solving tasks as described previously in this booklet, and copies them to the Assignment Manager as will be explained in this chapter. Only the workbook containing the Problem worksheets is distributed. The corresponding Solutions and Marking worksheets are saved in separate workbooks on the professor’s hard drive.</td>
<td>When used summative, there are normally several problem-solving tasks for a student to solve in conjunction with its matching Solution and Marking worksheets. Multiple-choice questions can also be included in the workbook (for implementation, see Lesson 3). A macro generates individual workbooks for each student and splits the individual workbooks into a Problem workbook and a corresponding workbook containing the Solution and Marking sheets. Another macro emails only the Problem workbooks to the students.</td>
</tr>
<tr>
<td>Student</td>
<td>Completes all Problem worksheets in the his/her individual Problem workbook. Submits his/her Problem workbook to the professor.</td>
<td>As specified above, the Solution and Marking worksheets are removed before Problem workbooks are distributed. When the students have finished their work, they reply to the original email and attach their completed Problem workbooks.</td>
</tr>
<tr>
<td>Professor</td>
<td>Merges the submitted Problem workbooks with the corresponding saved Solution and Marking workbooks. Grades workbooks. Sends feedback to students.</td>
<td>This is done automatically by clicking a button in the Assignment Manager (see Fig. 6.1). Click grading button and prepares a summary grading report containing grading statistics. The graded workbooks containing a detailed Feedback report can be sent by email to students by the professor clicking a button.</td>
</tr>
</tbody>
</table>
USING THE ASSIGNMENT MANAGER

The Assignment Manager (see Fig. 6.1) is designed to take care of all housekeeping related to summative assignments.

![Assignment Manager User Interface](image)

**Fig. 6.1.** The user interface of the Assignment Manager.
We will start by explaining the steps the professor needs to accomplish to prepare a summative assignment.

**Step 1: Save the workbook file ‘Automatic summative grading of problem-solving tasks’ with a new file name and use the new file as your template**

The workbook *Automatic summative grading of problem-solving tasks* is your starting point for submitting and grading problem-solving tasks, which are designed to be used summative. Save the template file with a new file name. It may be helpful to associate the file name with a corresponding course number and assignment date, e.g. *FIN_2020_Assignment_140215*.

**Step 2: Delete the example worksheets from your assignment file**

Three problem-solving tasks and one question worksheet are included in the template. When creating your own summative assignment, you must of course delete the pre-installed problem solving-tasks/questions. Assume you have saved the workbook file *Automatic summative grading problem-solving tasks* with the new filename *FIN_2020_Assignment_140215*.

1. Delete all example worksheets from the file *FIN_2020_Assignment_140215*, which is the three problem worksheets and the questions worksheet, and the corresponding solution and marking worksheets.

When you have deleted the example worksheets, four worksheets will remain in your assignment workbook: *Manager*, *EmailAddr*, *Scores*, and *Grades*.

**Step 3: Copy your own problem-solving task and question sheets to the assignment workbook**

Problem-solving tasks and questions are constructed the same way no matter how they are used (formatively or summative) except that, when used summative, no command buttons are included in the problem/question worksheets.

It is easier to test that automatic data generation and grading works as intended when the command buttons are available, therefore we recommend you to build your own
problem-solving tasks and questions as described in the previous chapters. When you are confident they work, you copy the problem, solution, and marking worksheets to your assignment workbook. However, be aware that when weighting the scores, now the sum of scores of all problem-solving tasks and questions must add up to 100.

1. Build your own problem-solving tasks and questions which you want to include in the assignment as described in the previous chapters of this booklet.
2. Adjust the scoring of each individual problem so that the sum of scores of all problems adds up to 100.
3. Copy the problems, solutions, and markings worksheets to your assignment workbook.
4. Delete the command buttons in every problem worksheets in the assignment workbook.

Now, we will continue by explaining how to submit an assignment using the Assignment Manager.

**Pre-execution Step 1: Test individual data generation**

After having completed the problem-solving tasks and/or multiple-choice questions comprising the assignment, you should test that individual data generation and grading works as intended before submitting the assignment.

1. In each problem worksheet, copy the existing facts to an empty range in the worksheet. In the questions worksheet, you can copy columns a:c to column l e.g.
2. Click Pre-execution Step 1 in the Assignment Manager.
3. Go to every problem worksheet and the question worksheet and control that new variates are generated.
4. When individual data generation works as intended, delete the copied facts in every problem worksheet and the question worksheet (see 1 above).
**Pre-execution Step 2: Test grading**

It may also be sensible to test the grading of the questions and problem-solving tasks before submitting the assignment. Before testing the grading, you must enter the score for every production rule in the Scores worksheet as explained in Execute Step 4: Score and grade assignments on page 59.

1. Enter the score for every production rule in the Scores worksheet as explained in Execute Step 4: Score and grade assignments on page 59.
2. Click the Pre-execution Step 2 in the Assignment Manager.
   In the Scores worksheet, all the production rules are scored, and the total score is 0 since none of the problems are solved yet.
3. Copy the solutions ranges in the solutions worksheet to the corresponding ranges in the problem worksheets so that all problems now are solved correctly.
4. Again, click the Pre-execution Step 2 in the Assignment Manager.
   In the Scores worksheet, the total score is now 100 since all problems are solved correctly.
5. By intention, make some mistakes in every problem worksheet and click Pre-execution Step 2 again. In the Feedback worksheet, control that your mistakes are commented and scored as expected.
6. To “reset” all the problem worksheets, click the Pre-execution Step 1 in the Assignment Manager.
7. Delete all the rows inserted in the Scores worksheet during the testing of the assignment.

When you are sure that you automatic data generation and grading works as intended, you are ready to submit your assignment. This, you accomplish by executing steps 1–5 in the Assignment Manager as described on the following pages.

**Execute Step 1: Generate semi-individual problem and solution files**

After having completed and tested the problem-solving tasks and/or multiple-choice questions comprising the assignment, Step 1 in the Assignment Manager can then be executed. This step generates individualized problems and solutions files for the specified number of students. The problems and solution files are saved in different
subfolders under the current folder of the Assignment Manager. These folders must be created prior to executing Step 1.

The files are saved in accordance with a file name prefix (*Candidate* in this example). The problem files are saved with the suffix *pro*, e.g., *Candidate 01_pro.xlsx*. Accordingly, the solution files are saved with *sol* as a suffix, e.g., *Candidate 01_sol.xlsx*. The number of problem-solving tasks included in a workbook must also be entered.

An assignment may include only problem-solving tasks, only multiple-choice questions, or both. If there are multiple-choice questions, the names of the question and the answer-key worksheets must be entered, and, finally, the question range.

**Execute Step 2: Hand-out problem files**

The problem files are delivered by email (MS Outlook). All students will receive the message entered into the message range in this step of the manager. The candidates’ numbers and their respective email-addresses are entered into the worksheet EmailAddr as shown in Fig. 6.2.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Candidate</td>
</tr>
<tr>
<td>2</td>
<td>Candidate 001_pro</td>
</tr>
<tr>
<td>3</td>
<td>Candidate 002_pro</td>
</tr>
<tr>
<td>4</td>
<td>Candidate 003_pro</td>
</tr>
<tr>
<td>5</td>
<td>Candidate 004_pro</td>
</tr>
<tr>
<td>6</td>
<td>Candidate 005_pro</td>
</tr>
<tr>
<td>7</td>
<td>Candidate 006_pro</td>
</tr>
<tr>
<td>8</td>
<td>Candidate 007_pro</td>
</tr>
<tr>
<td>9</td>
<td>Candidate 008_pro</td>
</tr>
<tr>
<td>10</td>
<td>Candidate 009_pro</td>
</tr>
<tr>
<td>2</td>
<td><a href="mailto:bbr020@post.uit.no">bbr020@post.uit.no</a></td>
</tr>
<tr>
<td>3</td>
<td><a href="mailto:abm022@post.uit.no">abm022@post.uit.no</a></td>
</tr>
<tr>
<td>4</td>
<td><a href="mailto:abo041@post.uit.no">abo041@post.uit.no</a></td>
</tr>
<tr>
<td>5</td>
<td><a href="mailto:afo029@post.uit.no">afo029@post.uit.no</a></td>
</tr>
<tr>
<td>6</td>
<td><a href="mailto:aga018@post.uit.no">aga018@post.uit.no</a></td>
</tr>
<tr>
<td>7</td>
<td><a href="mailto:ahe063@post.uit.no">ahe063@post.uit.no</a></td>
</tr>
<tr>
<td>8</td>
<td><a href="mailto:gje049@post.uit.no">gje049@post.uit.no</a></td>
</tr>
<tr>
<td>9</td>
<td><a href="mailto:gjo099@post.uit.no">gjo099@post.uit.no</a></td>
</tr>
<tr>
<td>10</td>
<td><a href="mailto:skk012@post.uit.no">skk012@post.uit.no</a></td>
</tr>
</tbody>
</table>

**Fig. 6.2.** The EmailAddr worksheet with e-mail addresses to the candidates.

**Execute step 3: Save submitted assignments**

When the students have completed their assignments, they submit them by replying to the email, which originally delivered the Problem files. To send all incoming assignments to a location other than the professor’s Inbox, a subfolder (FIN2020_AS1 in this example) of the professor’s Inbox in Outlook can be created, and a rule is implemented to automatically move messages with specific words to this
folder. When executing Step 3 in this example, all attachments are saved to the specified folder \c_Submitted) having the file suffix sub, e.g., Candidate 001_sub.xlsx.

**Manual cleaning of submitted file names**
With respect to the submitted files that are to be processed (see Execute Step 4), some manual filename “cleaning” must typically be performed prior to processing. All characters in the solution file names and the submitted file names must be equivalent, except for the three suffix-letters sol and sub. If the file Candidate 001_sub.xlsx does not match its corresponding solution file, Candidate 001_sol.xlsx, it will not be processed.

**Execute Step 4: Score and grade assignments**
Before scoring and grading assignments, the Scores and the Grades worksheets must be prepared.

**Preparing the Scores worksheet**
As the scoring process proceeds, scoring statistics will be entered into the Scores worksheet automatically, as illustrated in Fig. 6.3.

![Fig. 6.3. The Scores worksheet prepared for receiving scoring data.](image)

In the first row of the Scores worksheet, abbreviations for the six multiple-choice questions and the three problem-solving tasks in the assignment (see the workbook *Automatic summative feedback on problem-solving tasks*) have been entered. In the second row, the Weights of each item are entered as obtained from the respective marking sheets. The weights total to 100. The third row holds the header for each step.
Preparing the Grades worksheet

When the candidates are scored, a letter grading is prepared accordingly. The letter grades are based on the score range in cells E3:E8 with the corresponding grades in cells F3:F8 shown in Fig. 6.4. Changing the score range will of course change the grading. If more grades are needed, the table can be extended.

![Fig. 6.4. Preparing the Grading worksheet.](image)

When the Scores and Grades worksheets are prepared, Step 5 can be executed. This procedure enters scoring statistics into the Scores worksheet. When finished, it calculates an average score and standard deviation at every step.

![Fig. 6.5. Scoring statistics exemplified.](image)

The scoring procedure prepares a unique marking workbook for every student with a detailed customized feedback report. These workbooks are saved in the Marked folder and subsequently sent to the students by email (see Execute Step 5 below). The files are named with the candidate’s number and the suffix mar, e.g., Candidate
When the scoring is complete, the grades are compiled automatically in the Grades worksheet, as illustrated in Fig. 6.6.

![Grading distribution chart](image)

**Fig. 6.6.** Overall grading statistics and the grade distribution chart.

**Execute Step 5: Provide individual feedback to students**

Finally, the professor can send individual feedback to the students by e-mail. This step is executed following the same procedure as the delivery step (Execute Step 2) except that the filename suffix must be changed from *pro* to *mar*, e.g., *Candidate 001_mar.xlsx*, in the EmailAddr worksheet.
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## Appendix A: Overview marking parameters

### OVERVIEW OF MARKING PARAMETERS FOR PROBLEM-SOLVING TASKS

<table>
<thead>
<tr>
<th>Data generation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fact range</td>
<td>If more ranges, split by comma (,)</td>
</tr>
<tr>
<td>Fact orientation</td>
<td>If more ranges, split by comma (,)</td>
</tr>
<tr>
<td>Fact randomization</td>
<td>Type <strong>yes or no</strong></td>
</tr>
<tr>
<td>Output condition range</td>
<td>Type range</td>
</tr>
<tr>
<td>Simulation range</td>
<td>If more ranges, split by comma (,)</td>
</tr>
<tr>
<td>Number of possible answers</td>
<td>Only for regression problem-solving tasks</td>
</tr>
</tbody>
</table>

**Grading modeling problem-solving tasks**

| Model range     | If more ranges, split by comma (,) |
| Model orientation | If more orientations, split by comma (,) |
| Calculation range | If more ranges, split by comma (,) |
| Decision range   | Type range |
| IF formula with decision logic | Enter IF formula in cell |
| Question range   | Type range |

**Grading regression problem-solving tasks**

| Question range | If more ranges, split by comma (,) |
| Array model range | If more ranges, split by comma (,) |
| t-values range | If more ranges, split by comma (,) |
| Array orientation | Type **vertical** or **horizontal** |
| Array heading text | If more texts, split by comma (,) |
| Array formula range | Type range |
| Array formulas  | If more formulas, split by equal-sign (=) |
| Decision formula range | Type range |
| Decision formula | Enter formula, start by equal-sign (=) |
| Decision formula text | Enter text |
| Calculation range | If more ranges, split by comma (,) |

**Grading Optimization problem-solving tasks**

| Objective range     | Type range |
| Score objective     | Type a score (positive number less than 100) |
| Decision range      | Type range |
| Score decisions     | Type a score (positive number less than 100) |
| Constraint range    | Type range |
| Score constraints   | Type a score (positive number less than 100) |
| Constraint LHS range| Type range |
| Score constraints LHS | Type a score (positive number less than 100) |
Appendix B: Modifying the VBA code

A professor wanting to modify the VBA code is welcome to do so as long as this is accomplished for non-commercial purposes.

Figure A1. VBA code displayed in the VBA editor.