

Supplement to article published in
Journal of Accounting Education

Volume 32, Issue 1

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

IMPLEMENTATION GUIDE

Bernt Arne Bertheussen

Tromsø University Business School
UiT – The Arctic University of Norway
&
EDB Kunnskap as

Version 2/15/2014
ISBN: 978-82-7585-166-4

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 learners 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.

What must a professor do to succeed implementing the system on his/her own problem-solving tasks?	What will the professor achieve by implementing the system successfully?
1 Read in-depth the article <i>Power to Business Professors</i> in Journal of Accounting Education.	1 You will, as a Professor, be released from a lot time consuming (and boring) marking and grading work throughout the whole term.
2 Work through the tutorial lessons to get familiar with the system.	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.
3 Address relevant parts of the reference section.	

TABLE OF CONTENT

The aim of this guide _____ 3

PART 1: TUTORIAL

Lesson 1: Become familiar with the user interface _____ 5

Lesson 2: Creating an interactive problem-solving task _____ 12

Lesson 3: Supplementing with multiple-choice questions _____ 22

PART 2: REFERENCE MANUAL

Chapter 1: Point of departure; using problem-solving tasks formatively _____ 28

Chapter 2: Creating a goal-seeking problem-solving task _____ 32

Chapter 3: Creating a modeling problem-solving task _____ 35

Chapter 4: Creating an optimization problem-solving task _____ 42

Chapter 5: Creating a regression problem-solving task _____ 47

Chapter 6: Ending point; using problem-solving tasks summative _____ 53

INDEX _____ 62

APPENDIXES

Appendix A: Marking parameters _____ 65

Appendix B: Modifying the VBA code _____ 66

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.

	A	B
13	Data generation	
14	Fact range	b8:c11
15	Fact orientation	horizontal
16	Fact randomization	yes

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 contains a label.

Facts may be oriented horizontal or vertical. When you read row wise, the orientation is horizontal. Else, facts are vertical oriented.

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.

	A	B	C	D	E
7	Facts			<i>AVG</i>	<i>SD</i>
8	Stocks saving goal	830,000		850 000	50 000
9	Estimated returns on stocks	9% per month		10%	2%
10	Stocks market value	450,000 at saving sta		450 000	50 000
11	Monthly savings	3,700		3 500	350

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.

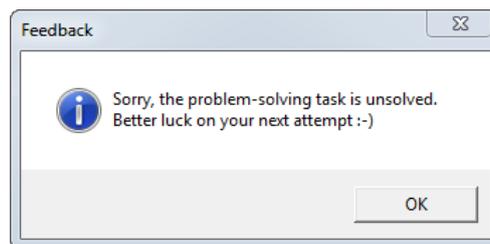


Fig. 1.3. A message box informs about an unsuccessful attempt.

- 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.

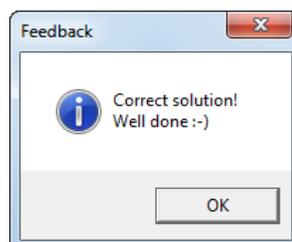


Fig. 1.4. A message box informs about a successful solution.

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.

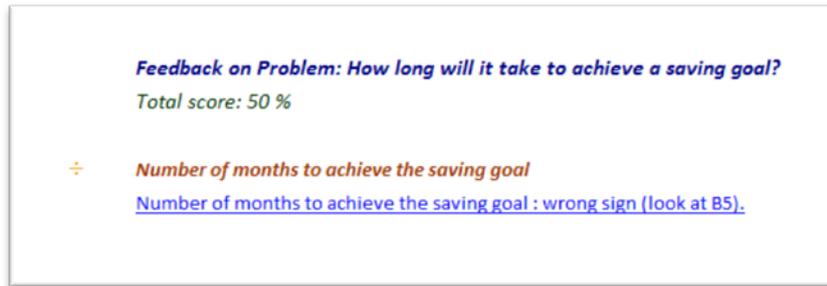


Fig. 1.5. The system gives feedback on a partial correct solution in a separate worksheet. If you click the hyperlink, you go to the erroneous cell.

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.

B5		fx =NPER(B11,-B8,-B10,B9)			
	A	B	C	D	
1	Problem: How long will it take to achieve a saving goal?				
2	Randy Hansson plans to buy an apartment in Spain. Instead of borrowing, she will save.				
3	She has invested in some stocks, and she keeps buying m per month		per month		
4					
5	Number of months it will take to achieve the saving goal	+ -7.8			Wrong sign. Grade

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.

B5		fx =NPER(B11,, -B10,B9)	
	A	B	C
1	Problem: How long will it take to achieve a saving goal?		
2	Randy Hansson plans to buy an apartment in Spain. Instead of borrowing, she will save		
3	She has invested in some stocks, and she keeps buying m per month	per month	
4			
5	<i>Number of months it will take to achieve the saving goal</i>	8.2	Grade
6			
7	Facts	Retry	
8	Monthly savings	3,500	
9	Stocks saving goal	920,000	
10	Stocks market value	390,000	at saving star
11	Estimated returns on stocks	11%	per month

Fig. 1.7. The reference to Monthly savings is removed from the formula in B5.

2 Grade the problem.

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

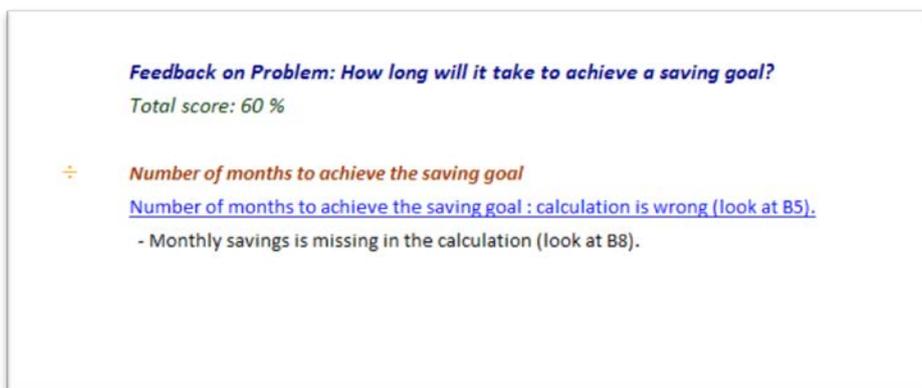


Fig. 1.8. The feedback report explains which variable is missing.

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.

	A	B	C
1	Problem: How long will it take to achieve a saving goal?		
2	Randy Hansson plans to buy an apartment in Spain. Instead of borrowing, she will se		
3	She has invested in some stocks, and she keeps buying m per month		per month
4			
5	<i>Number of months it will take to achieve the saving goal</i>	7.9	Grade
6			
7	Facts	Retry	
8	Monthly savings	3,500	
9	Stocks saving goal	920,000	
10	Stocks market value	390,000	at saving star
11	Estimated returns on stocks	11%	per month

Fig. 1.9. There is an error in the B5 formula.

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.

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

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.

	A	B	C	D	E	F
1	Problem: Establish the cash flow and calculate the true annual interest rate on an annuity loan					
2	Establish the cash flow to the loan below. Also, calculate the true annual interest rate on the loan.					
3						
4	True annual interest rate		Grade			
5						
6	Facts	Retry				
7	Loan amount	118 000	annuity, in arrears			
8	Years to maturity	4				
9	Instalment charge	570				
10	Number of instalments	1	per year			
11	Borrowing rate	4.5%	per year			
12						
13	Year	Cash flow				
14	0					
15	1					
16	2					
17	3					
18	4					
19	5					

Fig. 2.2. A problem worksheet based on the solution sheet in Fig. 2.1.

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.

	A	B	C	D	E
1	Marking: Establish the cash flow and calculate the true annual interest rate on an annuity				
2	Establish the cash flow to the loan below. Also, calculate the true annual interest rate on t				
3					
4	True annual interest rate				
5					
6	Facts			<i>AVG</i>	<i>SD</i>
7	Loan amount	106,000	annuity, in	100 000	10 000
8	Years to maturity	4			
9	Instalment charge	590		500	100
10	Number of instalments	1	per year		
11	Borrowing rate	5.1%	per year	5%	1%

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.

	A	B
25	Data generation	
26	Fact range	b7:c11
27	Fact orientation	horizontal
28	Fact randomization	yes

Fig. 2.4. Metadata related to the data generation.

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.

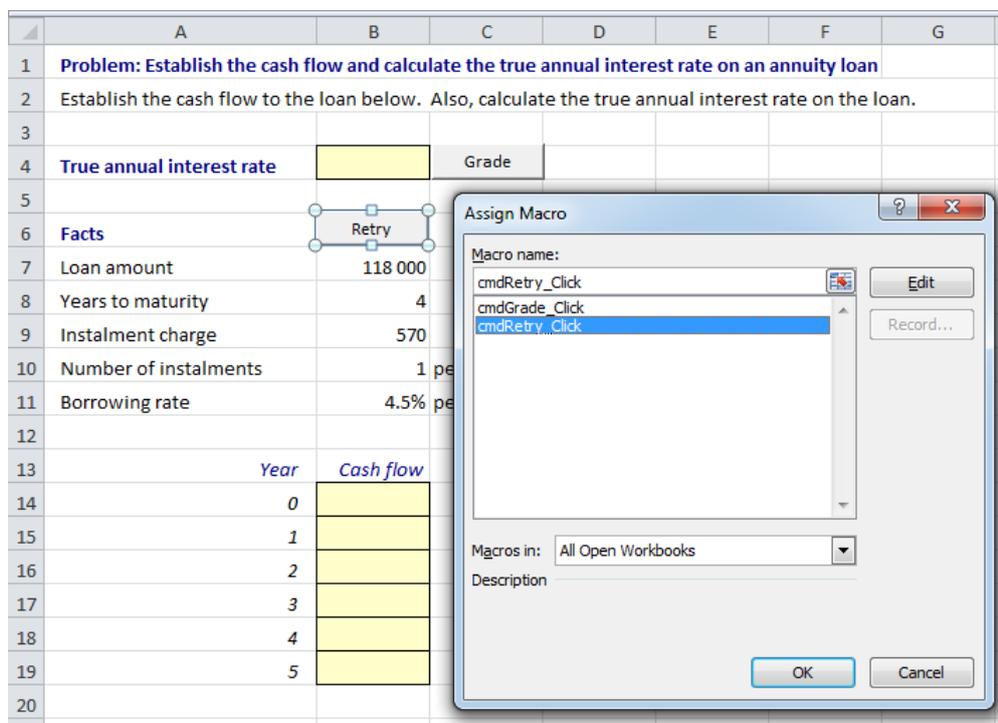


Fig. 2.5. Assigning the Retry button to the cmdRetry_Click macro.

- 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*.

	A	B	C	D	E	F
1	Marking: Establish the cash flow and calculate the true annual interest rate on an annuity loan					
2	Establish the cash flow to the loan below. Also, calculate the true annual interest rate on the loan.					
3		<i>Score</i>	<i>Address</i>	<i>Sign</i>	<i>Decimals</i>	
4	True annual interest rate	20	yes	50%	3	
5						
6	Facts			<i>AVG</i>	<i>SD</i>	
7	Loan amount	108,000	annuity, in	100 000	10 000	
8	Years to maturity	4				
9	Instalment charge	250		500	100	
10	Number of instalments	1	per year			
11	Borrowing rate	5.7%	per year	5%	1%	
12						
13	<i>Year</i>	<i>Cash flow</i>				
14	0	20				
15	1	20				
16	2	20				
17	3	20				
18	4	20				
19	5	- 30				
20	<i>Score</i>	80				
21	<i>Address</i>	yes				
22	<i>Sign</i>	50%				
23	<i>Decimals</i>	0				

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 ($20 \times 5 = 100$). 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.

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.

	A	B
29	Grading	
30	Calculation range	b4
31	Model range	a13:b19
32	Model orientation	vertical
33	Model axis established by student	no

Fig. 2.7. Grading parameters.

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*.

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

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.
- 2 Delete all content in the questions sheet that the student shall prepare, which is all yellow cells: (A2:A4, A10:A13, A16:A19, A27:A30, A33:A36, A39:A43).

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.

	A	B	C	D	E	F	G	H	I	J	K	
1	Question 1: How do you interpret the phrase 'the time value of money'?											
2		1 dollar today is worth more than one dollar in the future										
3		1 dollar today is worth less than one dollar in the future										
4		1 dollar today is worth as much as one dollar in the future										
5												
6	Question 2: Assume a positive interest rate. Which calculation must we perform to be able to add the amounts											
7	in year 0 and year 2 with the year 1 amount in the cash flow below?											
8	year 0	year 1	year 2									
9	100	100	100									
10		I can simply add the amounts as they are										
11		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										
12		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										
13		I can calculate the future value in year 1 of the amount in year 0 and the present value in year 1 of the amount in year 2 and then add them up										
14												
15	Question 3: Why do we need a cash flow to perform an investment analysis?											
16		we need a cash flow in order to calculate the present value of a project										
17		if we have the accounts, we do not need the cash flow of the project										
18		we need a cash flow in order to take into account the time value of money										
19		the cash flow gives us necessary additional information to the project accounts										
20												
21	Question 4: Which calculation is made in C26?											
22	Tax rate		28%									
23	Depreciation rate		16%									
24	Required rate of return		7%									
25	Investment		390 000									
26	Calculation		75 965									
27		the present value of tax saved due to depreciation is calculated										
28		the present value of the investment project is calculated										
29		the project profit after tax is calculated										
30		the present value of a growing perpetuity is calculated										
31												
32												
33	Grade		Retry									

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.

- 2 Activate the Parameters worksheet, select D13:I19, and press Ctrl+c to copy.
- 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.

	A	B	C	D	E	F
1	Scoring multiple-choice questions					
2	<i>Question</i>	<i>Start Cell</i>	<i>RndRng</i>	<i>Score</i>	<i>Knows Correct</i>	<i>Knows Wrong</i>
3	1	a1	a2:a4	15	60	20
4	2	a6	a10:a13	15	40	20
5	3	a15	a16:a19	15	35	15
6	4	a21	a27:a30	15	35	15
7	5	a32	a33:a36	20	55	15
8	6	a38	a39:a43	20	22	12
9						
10	<i>Question range</i>		a1:c43			

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.

Individual	Action	Comment
Professor	Prepares a workbook following the standard procedure described below.	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.	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 <i>xlVeryHidden</i> 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 <i>xlVeryHidden</i> as Visible-property.
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.

	A	B	C	D	E	F	
1	Solution: Calculating break-even point						
2	Do the required calculations and estimate the break-even point in units based on the facts below.						
3							
4	Facts						
5	Fixed costs	\$ 111,000					
6		<i>Per unit</i>	<i>Per batch</i>	<i>Per hour</i>			
7	Selling price	\$ 11.48					
8	Variable cost	\$ 5.74					
9	Setup cost		\$ 1,100				
10	Units produced		350				
11	Inspection costs			\$ 32			
12	Units inspected			17			
13	Activity driver	<i>Units sold</i>					
14							
15	Calculations						
16	Revenue	\$1,782,734					
17	Variable unit costs	-\$891,367					
18	Setup costs	-\$488,055					
19	Inspection costs	-\$292,311					
20	Fixed cost	-\$111,000					
21	Operating income	\$0					
22							
23	Question						
24	<i>BEP in units</i>	155,290					

Fig. 2.1. The solution worksheet of the goal-seeking problem-solving task exemplified in the workbook *Automatic formative grading of problem-solving task*.

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).

		B5				fx =ROUND(NORM.INV(RAND(),E5,F5),-3)	
	A	B	C	D	E	F	
1	Marking: Calculating break-even point						
2	Do the required calculations and estimate the break-even point in units based on the facts below						
3							
4	Facts				<i>AVG</i>	<i>SD</i>	
5	Fixed costs	103,000			\$100,000	\$10,000	
6		<i>Per unit</i>	<i>Per batch</i>	<i>Per hour</i>			
7	Selling price	\$ 9.83			\$10	\$1	
8	Variable cost	\$ 4.92					
9	Setup cost		\$ 1,000		\$1,000	\$100	
10	Units produced		300		400	50	
11	Inspection costs			\$ 29	\$30	\$3	
12	Units inspected			21	20	2	
13	Activity driver	<i>Units sold</i>					

Fig. 2.2. Random facts to the goal-seeking problem-solving task in Fig 2.1.

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.

	A	B
26	Data generation	
27	Fact range	b5:d12
28	Fact orientation	horizontal
29	Fact randomization	no

Fig. 2.3. Metadata related to the data generation of the goal-seeking problem-solving task in Fig. 2.1.

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.

	A	B
30	Grading Goal Seek	
31	Calculation range	b24,b16:b21
32	Goal seek: Set cell	b21
33	Goal seek: To value	0
34	Goal seek: Changing cell	b24

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.

	A	B	C
15	Calculations	<i>Score</i>	<i>Address</i>
16	Revenue	10	yes
17	Variable unit costs	10	yes
18	Setup costs	25	yes
19	Inspection costs	25	yes
20	Fixed cost	10	no
21	Operating income	10	yes
22			
23	Question	<i>Score</i>	<i>Address</i>
24	BEP in units	10	no

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.

	A	B	C	D	E	F	G
17							
18	<i>Model - projected cash flow year:</i>	0	1	2	3	4	5
19		▼					
20							
21							
22							
23							
24							
25							
26							

Fig. 3.1. The dropdown arrow attached to a data list.

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.

	A	B	C	D	E	F	G
17		<i>Project Cash Flow in Year:</i>					
18	<i>Model - projected cash flow year:</i>	0	1	2	3	4	5
19							
20	Cash Flow from Operations						
21	Depreciation						
22	Increased Taxes due to Impairments						
23	Investment and Disinvestment						
24	Net Cash Flow after Taxes						
25	Sales Revenue						
26	Saved Taxes due to Depreciations						
27	Taxes						

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).

	A
51	<i>Cash Flow from Operations</i>
52	<i>Depreciation</i>
53	<i>Increased Taxes due to Impairments</i>
54	<i>Investment and Disinvestment</i>
55	<i>Net Cash Flow after Taxes</i>
56	<i>Sales Revenue</i>
57	<i>Saved Taxes due to Depreciations</i>
58	<i>Taxes</i>

Fig. 3.3. The entries to a data list in the solution worksheet.

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.

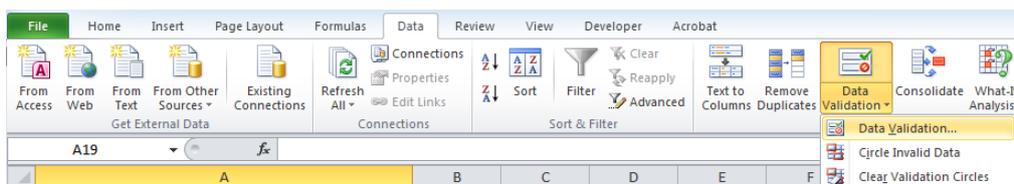


Fig. 3.4. Data Validation.

Finally, you can select List and specify the Source of the list in the dialog shown in Fig. 3.5.

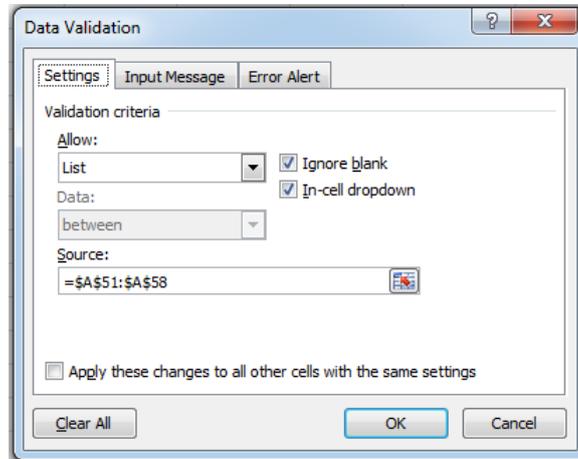


Fig. 3.5. The List option is selected and a Source range is entered.

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.

	A	B	C	D	E
9	Facts			<i>AVG</i>	<i>SD</i>
10	Investment	4,800,000	in year 0	5 000 000	300 000
11	Cash Flow from Operations	1,440,000	see Note 1	1 600 000	200 000
12	Disinvestment	2,300,000	see Note 2	2 500 000	150 000
13	Tax Rate	28%			
14	Declining Balance Depreciation Rate	19%		20%	2%
15	Required Rate of Return before Taxes	14%		15%	2%

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.

	A	B
28	Data generation	
29	Fact range	b10:c15
30	Fact orientation	horizontal
31	Fact randomization	yes

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.

	A	B
32	Grading	
33	Model range	a18:g26
34	Model orientation	horizontal
35	Model axis established by student	yes
36	Calculation range	b6
37	Decision range	b7
38	IF formula with decision logic	yes

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 models 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: =IF(B6>=0,"yes","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*.

	A	B	C	D	E	F	G	H	I	J	K
1	Marking: Is Investment Project Profitable?										
2	Adam Hansen has built popular wooden boats for many years. Now he considers investing in larger										
3	production capacity, but first he wants you to analyse the profitability of his project.										
4											
5		<i>Score</i>	<i>Address</i>	<i>Sign</i>	<i>Decimals</i>						
6	<i>Q1: Calculate project net present value</i>	10	yes	50%	0						
7	<i>Q2: Should project be accepted?</i>	5									
8											
17	<i>Project Cash Flow in Year:</i>										
18	Model - projected cash flow year:	0	1	2	3	4	5	<i>Score</i>	<i>Address</i>	<i>Sign</i>	<i>Decimals</i>
19	<i>Investment and Disinvestment</i>	50	- 25	- 25	- 25	- 25	50	10	no	50%	0
20	<i>Cash Flow from Operations</i>	- 50	20	20	20	20	20	5	yes	50%	0
21	<i>Taxes</i>	- 50	20	20	20	20	20	10	yes	50%	0
22	<i>Saved Taxes due to Depreciations</i>	100	- 20	- 20	- 20	- 20	- 20	15	yes	50%	0
23	<i>Increased Taxes due to Impairments</i>	100	- 20	- 20	- 20	- 20	- 20	15	yes	50%	0
24	<i>Depreciation</i>							10			
25	<i>Sales Revenue</i>							10			
26	<i>Net Cash Flow after Taxes</i>	17	17	17	17	16	16	10	no	50%	0

Fig. 3.9. Scoring a modeling problem-solving task.

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*.

	A	B	C	D	E	F	G	H	I	J	
1	Solution: Deciding product mix to maximize profit										
2	Quality Shirts Industries manufactures four varieties of ties. One is an expensive, all-silk shirt, one is an all-polyester shirt, and two										
3	are blends of polyester and cotton. Based on the facts below, you are asked to decide the product mix in order to maximize profit										
4											
5	Max Profit	137,541									
6											
7		All silk	All poly	Blend-1	Blend-2						
8	Number of units	7,500	12,101	14,119	8,200						
9	Selling price	8.37	3.84	4.52	5.12						
10	Labor cost	0.69	0.69	0.69	0.69						
11	Material cost	2.93	0.54	0.86	0.97						
12	Profit	4.75	2.61	2.97	3.46						
13											
14	Constraints					<i>Constr. LHS</i>	<i>Sign</i>	<i>Constr. RHS</i>			
15	Yards of silk	0.118				885	<=	1,000			
16	Yards of polyester		0.08	0.048	0.031	1,900	<=	1,900			
17	Yards of cotton			0.052	0.069	1,300	<=	1,300			
18	Maximum all silk	1				7,500	<=	7,500			
19	Maximum all poly		1			12,101	<=	16,000			
20	Maximum blend-1			1		14,119	<=	16,000			
21	Maximum blend-2				1	8,200	<=	8,200			
22	Minimum all silk	1				7,500	>=	6,000			
23	Minimum all poly		1			12,101	>=	10,000			
24	Minimum blend-1			1		14,119	>=	13,000			
25	Minimum blend-2				1	8,200	>=	6,100			

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.

	A	B	C
40	Data generation		
41	Fact range	b9:e11, b15:e17, h15:h25	
42	Fact orientation	horizontal, horizontal, vertical	
43	Fact randomization	no, no, no	
44	Output condition range	b37:b38	

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.

	A	B	C	D	E	F	G	H	I
4									
5	Max Profit	100							
6									
7		All silk	All poly	Blend-1	Blend-2				
8	Number of units	25	25	25	25				
9	Selling price	6.79	3.52	4.43	5.43				
10	Labor cost	0.90	0.90	0.90	0.90				
11	Material cost	2.38	0.49	0.84	1.03				
12	Profit	3.51	2.13	2.69	3.50				
13									
27		All silk AVG	All silk SD	Poly AVG	Poly SD	Blend-1 AVG	Blend-1 SD	Blend-2 AVG	Blend-2 SD
28	Selling price	7.0	0.7	3.5	0.4	4.3	0.3	4.8	0.4
29	Labor cost	0.8	0.1						

Fig. 4.3. Random Selling price, Labor cost, Material cost, and Profit is chosen from a Normal distribution.

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.

	H	I	J	K	L	M
14	<i>Constr. RHS</i>	<i>Constr. AVG</i>	<i>Constr. SD</i>			
15	1,000	1,000	50			
16	2,100	2,000	100			
17	1,300	1,250	50			
18	7,000	7,000	350			
19	15,000	14,000	1000			
20	15,000	16,000	1000			
21	8,600	8,500	400			
22	5,700	6,000	300			
23	10,000	10,000	500			
24	13,000	13,000	1000			
25	5,700	6,000	300			

Fig. 4.4. Right-hand side constraints (*Constr. RHS*) are generated from a Normal distribution.

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.

	A	B	C	D
35	<i>Output conditions</i>			
36	<i>Variable</i>	<i>Condition</i>		
37	Price B-1 vs Price B-2	TRUE		
38	M cost B-1 vs M cost B-2	TRUE		

Fig. 4.5. Output conditions.

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.

	A	B
45	Grading Optimization	
46	Objective range	b5
47	Score objective	30
48	Decicion range	b8:e8
49	Score decicions	20
50	Constraint range	b18:e25
51	Score constraints	20
52	Constraint LHS range	f15:f25
53	Score constraints LHS	30

Fig. 4.6. Metadata for grading and scoring relevant for the optimization problem-solving task in Fig. 4.1.

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.

	A	B	C	D	E
5	Max Profit	100			
6					
7		All silk	All poly	Blend-1	Blend-2
8	Number of units	25	25	25	25

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

	A	B	C	D	E	F
14	Constraints					<i>Constr. LHS</i>
15	Yards of silk	0.109				9
16	Yards of polyester		0.081	0.055	0.035	9
17	Yards of cotton			0.045	0.065	9
18	Constraint: Maximum all silk	13	-4	-4	-4	9
19	Constraint: Maximum all poly	-4	13	-4	-4	9
20	constraint: Maximum blend-1	-4	-4	13	-4	9
21	Constraint: Maximum blend-2	-4	-4	-4	13	9
22	Constraint: Minimum all silk	13	-4	-4	-4	9
23	Constraint: Minimum all poly	-4	13	-4	-4	9
24	Constraint: Minimum blend-1	-4	-4	13	-4	9
25	Constraint: Minimum blend-2	-4	-4	-4	13	10

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

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*.

	A	B	C	D	E	F	G	H	I	J
1	Solution: Regression and cost estimation									
9										
10	House	Square Feet	Openings	Cost						
11	1	2,182	11	\$2,727						
12	2	2,236	11	\$2,774						
13	3	1,893	10	\$2,406						
14	4	2,047	11	\$2,608						
15	5	2,049	11	\$2,626						
16	6	2,030	10	\$2,619						
17	7	1,795	9	\$2,312						
18	8	2,017	10	\$2,470						
19	9	1,833	9	\$2,233						
20	10	2,052	10	\$2,576						
21	11	2,052	11	\$2,565						
22	12	1,949	10	\$2,343						
23										
24	Q1: estimate variable cost per square foot				1.24					
25	Q2: estimate variable cost per opening				0.00					
26	Q3: estimate fixed cost				31.66					
27	Q4: estimate the cost of painting a house				1,905	Sq Ft with	8	Openings	2,390	Please, type 'insignificant' in th
28										
29		Openings	Square Feet	Fixed Cost		Square Feet	Fixed Cost		Openings	Fixed Cost
30	Linest	40.02	1.04	20.33		1.24	31.66		190.44	569.57
31		44.30	0.26	278.19		0.14	275.34		37.32	383.51
32		0.90	58.91	#N/A		0.89	58.37		0.72	93.31
33		40.70	9.00	#N/A		82.08	10		26.04	10.00
34		282,497	31,238	#N/A		279,664	34,071		226,671.21	87,063.71
35	t values	0.90	4.01	0.07		9.06	0.11		5.10	1.49

Fig. 5.1. The solution worksheet to a regression problem-solving task exemplified.

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.

	A	B
37	Data generation	
38	Fact range	b11:d22
39	Fact orientation	vertical
40	Fact randomization	no
41	Output condition range	k20:k22
42	Simulation range	d27, f27
43	Number of possible answers	4

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.

B11 fx {=INT(cholesky(\$G\$11:\$I\$11))}										
A	B	C	D	E	F	G	H	I	J	K
1 Marking: Regression and cost estimation										
9										
10	House	Square Feet	Openings	Cost	Mean	Square Feet	Openings	Cost		
11	1	1,870	9	\$2,365	Mean	2,000	10	2,500		
12	2	2,139	10	\$2,681						
13	3	1,734	8	\$2,030						
14	4	2,050	10	\$2,677						
15	5	1,915	9	\$2,368						
16	6	1,493	7	\$1,772						
17	7	2,189	10	\$2,736						
18	8	2,228	11	\$2,868						
19	9	1,982	10	\$2,533	Conditions					
20	10	1,897	9	\$2,487	Fixed cost	44.59	155.23	2.63		TRUE
21	11	2,058	10	\$2,644	VC per unit	140.85	0.55	1.16	261.77	TRUE
22	12	1,937	9	\$2,581	Model choice	1.64	1.45			TRUE

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:

```
{=INT(cholesky($G$11:$I$11))}
```

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.

K20 fx {=AND(G20:I20>0)}						
	F	G	H	I	J	K
19	Conditions					
20	Fixed cost	44.59	155.23	2.63		TRUE
21	VC per unit	140.85	0.55	1.16	261.77	TRUE
22	Model choice	1.64	1.45			TRUE

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.

K22		fx {=IF(B43=1,AND(G22:H22>2),IF(B43=2,AND(G22<2,H22>2),IF(B43=3,AND(G22>2,H22<2),IF(B43=4,AND(G22:H22<2))))))}									
	F	G	H	I	J	K	L	M	N	O	P
19	Conditions										
20	Fixed cost	44.59	155.23	2.63		TRUE					
21	VC per unit	140.85	0.55	1.16	261.77	TRUE					
22	Model choice	1.64	1.45			TRUE					

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.

	A	B	C	D	E	F	G	H	I	J	K
44	Grading Regression										
45	Question range	e24:e26, h27									
46	Array model range	b30:d34, f30:g34, i30:j34									
47	t-values range	b35:d35, f35:g35, i35:j35									
48	Array orientation	vertical									
49	Array heading text	Regression 1: Openings, Square Feet, Fixed Cost; Regression 2: Square Feet, Fixed Cost; Regression 3: Openings, Fixed Cost									
50	Array formula range	e24:e26									
51	Array formulas	=IF(AND(B35:C35>2),C30,IF(C35>2,F30,0))=IF(AND(B35:C35>2),B30,IF(B35>2,I30,0))=IF(AND(B35:C35>2),D30,IF(AND(B35:C35<2),0,IF(B35>2,J30,G30)))									
52	Decision formula range	h27									
53	Decision formula	=E24*D27+E25*F27+E26									
54	Decision formula text	Both cost drivers are statistically insignificant and we need to look for new cost drivers.									
55	Calculation range	b35:c35,f35,i35, h27									

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.

	A	B	C	D	E	F	G	H	I	J
24	Q1: estimate variable cost per square foot				14					
25	Q2: estimate variable cost per opening				14					
26	Q3: estimate fixed cost				14					
27	Q4: estimate the cost of painting a house			2,172	Sq Ft with	12	openings	22		
28										
29		Openings	Square Feet	Fixed Cost		Square Feet	Fixed Cost		Openings	Fixed Cost
30	Linest	10				6			6	
31										
32										
33										
34										
35	t-values	2	2	2		2	2		2	2

Fig. 5.7. Scoring a regression problem-solving task.

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.

Individual	Action	Comment
Professor	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.	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).
	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.	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.
Student	Completes all Problem worksheets in the his/her individual Problem workbook.	As specified above, the Solution and Marking worksheets are removed before Problem workbooks are distributed.
	Submits his/her Problem workbook to the professor.	When the students have finished their work, they reply to the original email and attach their completed Problem workbooks.
Professor	Merges the submitted Problem workbooks with the corresponding saved Solution and Marking workbooks.	This is done automatically by clicking a button in the Assignment Manager (see Fig. 6.1).
	Grades workbooks.	Click grading button and prepares a summary grading report containing grading statistics.
	Sends feedback to students.	The graded workbooks containing a detailed Feedback report can be sent by email to students by the professor clicking a button.

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

Pre-execution Step 1
 Test individual data generation

Pre-execution Step 2
 Test grading of questions and problem-solving tasks

Step 1: Generate and save Problem & Solution files to hard drive

Enter number of students	10
Enter path to Problem files	\a_Problems\
Enter path to Solution files	\b_Solutions\
Enter File name prefix	Candidate

If Multiple Choice Questions

Enter Question Sheet name	Questions
Enter Answer Key Sheet name	Answers
Enter Question range	a1:c43

If Practice Problems

Enter Problem Sheet name Prefix	Problem
Enter Solution Sheet name Prefix	Solution
Enter Number of Problems to solve	3

Step 2: Enter email text below and hand-out Problem files

Mandatory assignment in Finance FIN-2020
 In the attached Excel workbook, you will find Questions and Problems. Download the file attachment, answer the questions and solve the problems within 60 minutes. When finished, please attach your solution and reply to this email.

Step 3: Save submitted assignments to hard drive

Enter name of Outlook folder with attachments	FIN2020_AS1
Save attachments in the folder	\c_Submitted\

Step 4: Mark assignments

Enter path to folder with marked submissions	\d_Marked
--	-----------

Step 5: Enter email text below and provide individual feedback on assignments to students

Feedback on mandatory assignment in Finance FIN-2020
 In the attached Excel workbook, you will find detailed feedback on your assignment. Download the file and use the feedback to improve your solutions.

 Well done :)

Execute Step 1
 Generate semi-individual problem and solution files

Execute Step 2
 Hand-out problem files

Execute Step 3
 Save submitted assignments

Execute Step 4
 Score and grade assignments

Execute Step 5
 Provide individual feedback to students

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.

	A	B
1	Candidate	E-mail Address
2	Candidate 001_pro	bbr020@post.uit.no
3	Candidate 002_pro	abm022@post.uit.no
4	Candidate 003_pro	abo041@post.uit.no
5	Candidate 004_pro	afo029@post.uit.no
6	Candidate 005_pro	aga018@post.uit.no
7	Candidate 006_pro	ahe063@post.uit.no
8	Candidate 007_pro	aje049@post.uit.no
9	Candidate 008_pro	ajo099@post.uit.no
10	Candidate 009_pro	aki012@post.uit.no

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.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	Q & P	Q1	Q2	Q3	Q4	Q5	Q6	P1	P2a	P2b	P2c	P2d	P3a	P3b	P3c	P3d	P3e	P3f	P3g	P3h	
2	Weights	5	5	5	5	5	5	10	12	3	3	2	4	6	4	8	8	4	4	2	100
3	Candidates	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11	Step 12	Step 13	Step 14	Step 15	Step 16	Step 17	Step 18	Step 19	Total Score
4																					

Fig. 6.3. The Scores worksheet prepared for receiving scoring data.

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.

	D	E	F	G	H
1	Letter grading and grading distribution				
2	Score range		Grade	Number	%
3		0	F	0	
4		40	E	0	
5		50	D	0	
6		65	C	0	
7		80	B	0	
8		90	A	0	
9				0	

Fig. 6.4. Preparing the Grading worksheet.

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.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	
1	Q & P	Q1	Q2	Q3	Q4	Q5	Q6	P1	P2a	P2b	P2c	P2d	P3a	P3b	P3c	P3d	P3e	P3f	P3g		
2	Weights	5	5	5	5	5	5	10	12	3	3	2	4	4	8	8	4	8	4	100	
3	Candidates	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11	Step 12	Step 13	Step 14	Step 15	Step 16	Step 17	Step 18	Total Score	
117	Candidate 015_mar	80	80	85	100	70	70	80	0	0	0	100	0	0	0	0	0	0	0	0	34
118	Candidate 005_mar	20	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	96
119	Candidate 116_mar	100	40	100	100	70	20	80	5	100	100	100	100	100	100	100	100	100	100	100	78
120	Candidate 071_mar	100	40	100	100	70	20	80	5	100	100	100	100	100	100	100	100	100	100	100	78
121	Candidate 115_mar	30	0	0	70	30	30	0	0	0	0	0	100	100	90	90	100	0	0	0	34
122	Candidate 133_mar	100	40	100	100	70	20	80	5	100	100	0	100	100	100	100	100	100	100	100	76
123	Candidate 140_mar	20	100	100	85	100	100	80	100	100	33	100	100	100	100	100	100	100	100	100	91
124	Candidate 050_mar	100	100	100	100	100	70	80	100	100	100	100	100	100	100	100	100	100	100	100	96
125	Candidate 002_mar	70	100	100	30	70	100	80	0	0	100	0	100	100	40	40	100	72	100	100	63
126	Candidate 001_mar	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
127	AVG	60	68	88	84	77	74	75	53	79	73	70	87	80	78	79	81	76	82	74	
128	SD	32	32	29	27	23	26	26	49	41	42	46	28	40	35	34	39	40	38	21	

Fig. 6.5. Scoring statistics exemplified.

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

001_mar.xlsx. When the scoring is complete, the grades are compiled automatically in the Grades worksheet, as illustrated in Fig. 6.6.

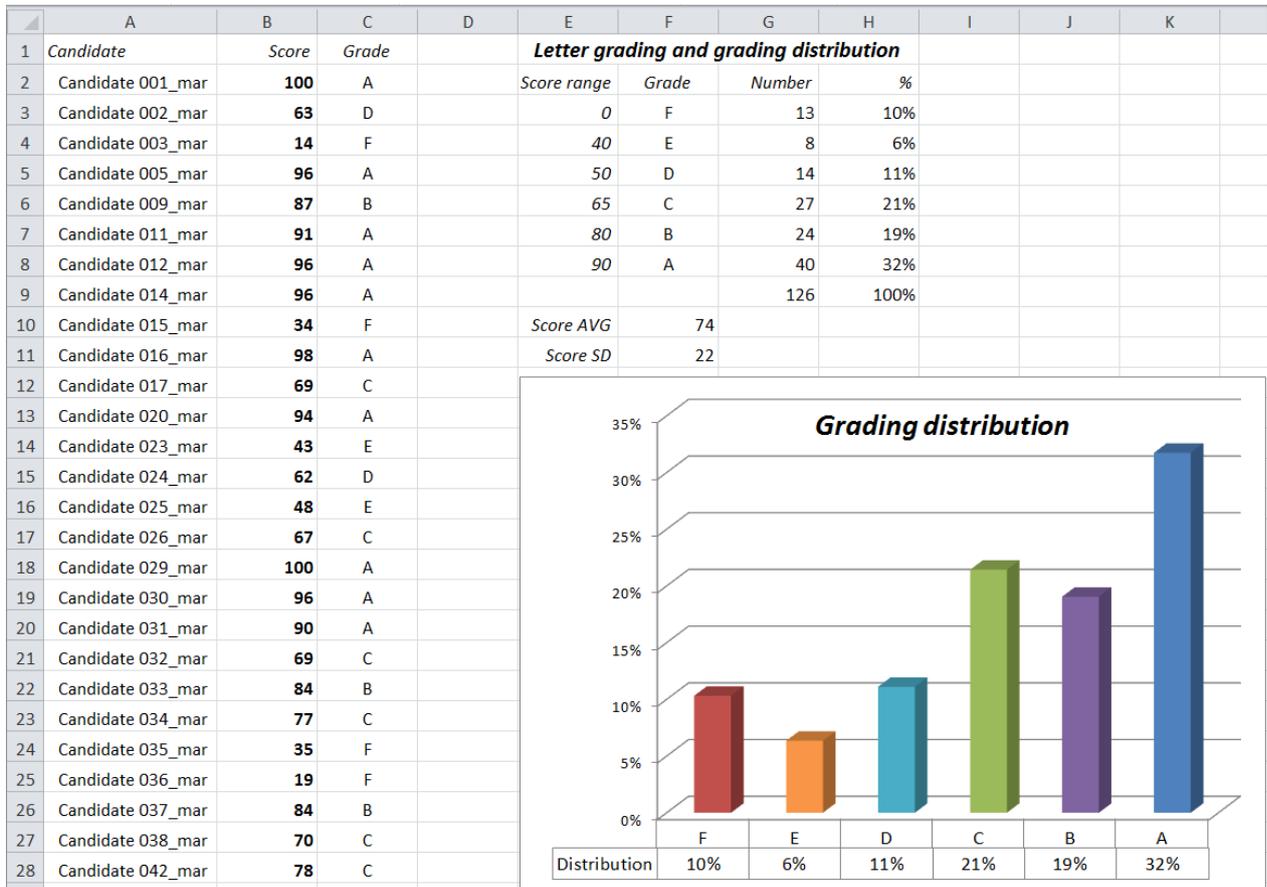


Fig. 6.6. Overall grading statistics and the grade distribution chart.

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.

Index

#NUM-message 15-16

A

Address parameter 19

Aim of this guide 2

AND-operator 50

Answer worksheet 22

Array formulas 47

Assign Macro 17

Assignment Manager 54

- preparing an assignment 55-57

- submitting an assignment 57-61

Assignment,

- generating semi-individual problem and solution files 57

- grading distribution chart 61

- handing out problem files 58

- letter grading 60

- manual cleaning of submitted file names 59

- preparing an assignment 55-57

- providing individual feedback to students 61

- saving submitted assignments 58

- score and grade assignments 59

- scoring statistics 60

- submitting an assignment 57-61

Automatic formative grading problem-solving tasks.xls 28

B

Build a new problem solving task 30

C

Cholesky function 48-49

Creating an interactive problem-solving task 12

- copy command buttons 13

- general procedure 28-31

- generate randomized facts variates 14-15

- prepare the market worksheet 14

- prepare the problem worksheet 13

- random data generation 16

- scoring the problem-solving task 13

D

Data List 35-36

Data Validation 36-37

Distractor labels 36

F

Fact randomization, refresh values only 6

Feedback report 9

Formative use of problem-solving tasks 28

- sequence of events 28

G

Goal-seeking problem-solving task 32

- generate random facts 32-33

- grading parameters 32

- scoring parameters 32

- solution worksheet exemplified 32

Grade button 7

Grade multiple-choice questions 25

Grading distribution chart 61

Grading parameters 20

H

Hide worksheets 31

Hide worksheets, very hidden 31

I

IF-function 39, 49

L

Lesson 1: the user interface 5

Lesson 2: create a problem-solving task 5

Lesson 3: multiple-choice questions 22

Letter grading 60

LINEST-function 47

M

Marking parameters 66

MarkingQst worksheet 25

Model choice condition 50

Modeling problem-solving task 35

 create a data list 35-36

 generate random facts 35

 grading parameters 38

 score a production rule 39

 scoring parameters 39

Multiple-choice questions 22

 KnowsCorrect 25

 KnowsWrong 25

 option ranges 25

 Question range 25

 RndRng 25

 Score 25

 start cell 25

 stem cells 25

N

NORM.INV-function 33, 37, 44

O

Optimization problem-solving task 42

 facts generation 43

 generating right-hand constraints 45

 output conditions 45

 scoring and grading constraints 46

 scoring and grading objective and
 decisions 46

 scoring and grading production rules
 45-46

 solution worksheet exemplified 42

Output conditions 45, 49

P

Problem-solving tasks used formatively 28

R

RANDBETWEEN-function 51

RAND-function 38, 44

Reference manual 27

Regression problem-solving task 47

 grading parameters 51

 meta data to data generation 48

 model choice condition 50

 scoring 52

 setting output conditions 49

 simulation values 51

 solution worksheet exemplified 47

 using Cholesky function 48-49

Retry button 5

ROUND-function 33, 37, 44

S

Score

 a calculation 11

 a distractor item 40

 a partially correct formula 40

 a production rule 18

 a production rule 39

 decimal places 41

 individual cell addresses 9-10

- irrelevant production rule 40
- multiple-choice questions 25
- subsets of a production rule 40

Scoring statistics 60

Scoring subsets of a production rule 19

Sign in a calculation 8

Sign parameter 20

Summative use of problem-solving tasks

- using Assignment Manager 54

- sequence of events 53

T

Template workbook for automatic

- formative grading 28

- summative grading 55

Tutorial 4

Tutorial_problem.xls 5

Tutorial_solution.xls 21

V

VBA-editor 31, 68

Appendix A: Overview marking parameters

OVERVIEW OF MARKING PARAMETERS FOR PROBLEM-SOLVING TASKS

Data generation

	Comments
Fact range	If more ranges, split by comma (,)
Fact orientation	If more ranges, split by comma (,)
Fact randomization	Type yes or no
Output condition range	Type range
Simulation range	If more ranges, split by comma (,)
Number of possible answers	Only for regression problem-solving tasks

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)

Grading goal-seeking problem-solving tasks

Calculation range	Type range
Goal seek: Set cell	Type range
Goal seek: To value	Type value
Goal seek: Changing cell	Type range

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.

```

Sub cmdRetry_Click()
    Dim sShtFullName As String, sShtNo As String, sFacts() As String, sFactsRngProblSol() As String, sFactsRngMarking() As String, sFactsRngOrientation() As String, sFactsRngRandomization() As String
    Dim wsMarking As Worksheet

    On Error Resume Next

    sShtFullName = ActiveSheet.Name
    sShtNo = Right(ActiveSheet.Name, 1)

    If IsNumeric(sShtNo) = False Then
        RandomizeQuestItems
    Else
        Set wsMarking = Worksheets("Marking" & " " & sShtNo)

        sFactsRngMarking = Split(wsMarking.Cells.Find(What:="Fact range", LookAt:=xlWhole).Offset.End(xlToRight), ",")
        sFactsRngProblSol = Split(wsMarking.Cells.Find(What:="Fact range", LookAt:=xlWhole).Offset(0, 1), ",")
        sFactsOrientation = Split(wsMarking.Cells.Find(What:="Fact orientation", LookAt:=xlWhole).Offset(0, 1), ",")
        sFactsRandomization = Split(wsMarking.Cells.Find(What:="Fact randomization", LookAt:=xlWhole).Offset(0, 1), ",")

        ' If randomization is not included in Marking sheet ... Necessary to call NewRandomizeRN
        If Err.Number = 91 Then
            For i = 0 To UBound(sFactsOrientation)
                ReDim sFactsRandomization(UBound(sFactsOrientation))
                sFactsRandomization(i) = sFactsOrientation(i)
            Next i
        End If

        ' Removing blanks
        If UBound(sFactsRngProblSol) > 0 Then
            For i = 0 To UBound(sFactsRngProblSol)
                sFactsRngProblSol(i) = Trim(sFactsRngProblSol(i))
            Next i
            For i = 0 To UBound(sFactsOrientation)
                sFactsOrientation(i) = Trim(sFactsOrientation(i))
            Next i
            For i = 0 To UBound(sFactsRandomization)
                sFactsRandomization(i) = Trim(sFactsRandomization(i))
            Next i
        End If

        For i = 0 To UBound(sFactsRngMarking)
            NewRandomizeRN sShtFullName, sShtNo, sFactsRngMarking(i), sFactsRngProblSol(i), sFactsOrientation(i), sFactsRandomization(i)
        Next i
    End If

    Application.ScreenUpdating = True
End Sub

```

Fig. A1. VBA code displayed in the VBA editor.