SIMPLE SPREADSHEET MODELING BY FIRST-YEAR BUSINESS UNDERGRADUATE STUDENTS: DIFFICULTIES IN THE TRANSITION FROM REAL WORLD PROBLEM STATEMENT TO MATHEMATICAL MODEL

Djordje Kadijevich
Mathematical Institute SANU and Megatrend University, Serbia
Email: djkadijevic@megatrend-edu.net

Abstract. The study used a sample of first-year business undergraduate students who developed simple (deterministic & non-optimization) models with Microsoft Excel. The students were required to choose business of their choice and give recommendations to have it profitable or more profitable. To help them achieve this end, the teacher presented to the students his solution regarding a taxi business within a local area, having previously explained to the students various ways to do "what-if" analyses. By referring to the framework of Galbraith and Stillman (2006), this paper mainly presents some of frequent modelers' difficulties regarding the transition from real world problem statement to mathematical model. These difficulties deal with selecting variables, initializing variables, and relating variables. Possible reasons for such difficulties and suggestions for further research are included.

Introduction

In general, many students experience difficulties in moving between the real and the mathematical world (Crouch & Haines, 2004). This is particularly true for genuine modeling tasks (e.g. Choose business of your choice and give recommendations to have it profitable or more profitable) where modelers have to formulate problems to solve in mathematical terms. It is thus important to realize and appropriately deal with the role of context in the modeling process (Galbraith & Stillman, 2001). The use of technology may improve the matters (see Keune & Nenning, 2003), enabling us to concentrate on subtasks causing the most difficulties in moving between the real and the mathematical world. To achieve this end, Microsoft Excel can be used. As regards business applications, this software can be used for "what-if" and optimization analyses (Conway & Ragsdale, 1997; Teo & Tan, 1999). Moreover, it can be used as a DSS (Decision Support System) tool (Coles & Rowley, 1996; Heys, 2008), especially when various add-ins are utilized (e.g. SimTools for simulations, RiskOptimizer for simulations with optimizations, and XLMiner for data mining). It is important to underline that although utilizing powerful technology can promote better understanding of mathematics (Kadijevich, Haapasalo & Hvorecky, 2005), students may find challenging to develop a technology-based solutions to problems whose underlying mathematics is known to them (see Parramore, 2007).

Through searching for critical aspects relevant to transitions between main stages in the modeling process (messy real world situation, real word problem statement, mathematical model, mathematical solution, real world meaning of mathematical solution, and evaluation—revise model or accept solution), Galbraith and Stillman (2006) find that the transition from real world problem statement to mathematical model is one of the most difficult part of the modeling cycle. As regards this transition, being concerned with technology-supported modeling, these researchers recognize the following nine critical activities:

1. Identifying dependent and independent variables for inclusion in algebraic model,
2. Realizing that independent variable must be uniquely defined,
3. Representing elements mathematically so formulae can be applied,
4. Making relevant assumptions,
5. Choosing technology/mathematical tables to enable calculation,
6. Choosing technology to automate application of formulae to multiple cases,
7. Choosing technology to produce graphical representation of model,
8. Choosing to use technology to verify algebraic equation,
9. Perceiving a graph can be used on function graphers but not data plotters to verify an algebraic equation. (see p. 147)

By using a sample of first-year business undergraduate students who developed simple (deterministic & non-optimization) models with Microsoft Excel, we analyzed the shortcomings of the developed models. This analysis evidenced that many modelers are likely to fail in selecting variables, initializing variables, and relating variables. These three areas of shortcomings, which are respectively related to the above-mentioned activities 1&2, 4, and 3, are exemplified in a section to follow. Before this section we describe the learning task to be done and the help offered to the modelers.

Learning task and help offered

Learning task

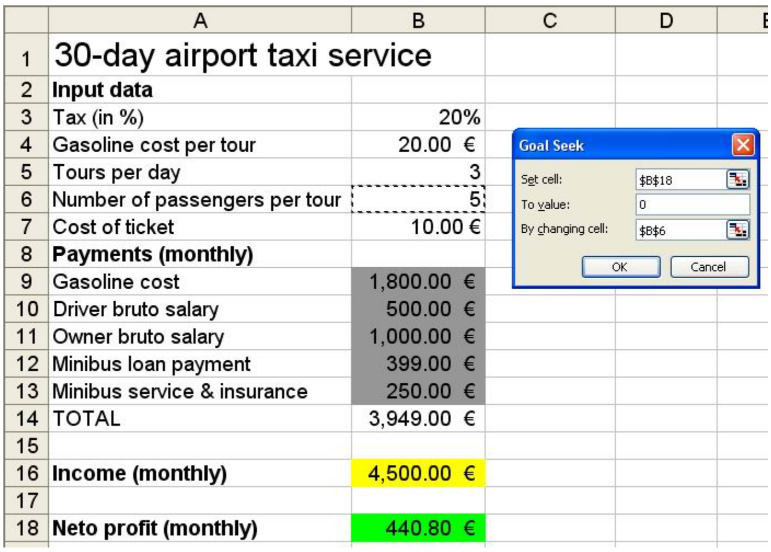
The students were required to choose business of their choice and give recommendations to have it profitable or more profitable.

Bearing in mind that prior modelers' competences of applicable mathematics and technology are to be ensured (Galbraith & Stillman, 2006), we tried to make both mathematical and technological prerequisites as simple as possible. Indeed, the developed models just reflected simple deterministic and non-optimization business situations, as will be exemplified by spreadsheet screenshots given below. Furthermore, required Excel tools (or commands to more precise) only dealt with "what-if" analyses.

Because of such prerequisites, learning challenges were mostly related to three transitions: from messy real world solution to real word problem statement, from real world problem statement to mathematical model, and from evaluation to report. Contrary to students in Galbraith and Stillman (2006) who, for example, used video animations to clarify situations to be modeled, our students had themselves to cope with all these learning challenges. However, a modest help was offered to the students.

Help offered

Having previously explained to the students various ways to achieve "what-if" analyses within Excel by using its commands Tools/Goal Seek, Data/Table, and Tools/Scenarios, the teacher (the author of this paper) presented to the students his solution regarding a taxi business within a local area. The goal (How to make business profitable?) was achieved through answering the following question: How many passengers, on average, are required by a profitable taxi business? This question was answered with the Goal Seek command that found the number of passengers when the sum of required payments and an expected income equaled zero. This is represented on Screenshot 1.



Screenshot 1. Help provided

For these data, the Goal Seek returns 4,39 passengers. A model-grounded business recommendation would be: “For 3 tours per day and a 10-EUR ticket, the number of passengers should at least be 4 or 5, with 5 present less often!” or “Very rarely have tours with less than 4 passengers!”

Findings

The modelers worked on a modeling project that lasted 3-4 week. They mostly worked in groups with 2 or 3 students. As this task was optional, just 20-30% of all students chose to work on it. About fifteen solutions to this task were analyzed for each of the two last academic years. The subsections to follow summarize main shortcomings regarding selecting, initializing, and relating variables. Note that these tree types of shortcomings, which emerged from an informal and explorative study, usually influence each other.

Selecting variables

This shortcoming frequently occurs when modeler fails to view the costs of a production or a service through its fixed and variable parts. Consider, for example, celebrating an anniversary. The costs for a music band and a place to be rented do not depend on the number of participants, whereas the costs for food and drink to be served do so. Screenshot 2 illustrates this shortcoming. Although the modelers made the distinction between fixed and variable costs, these costs were in fact all fixed as the datum for the number of guests was not used.

It is important to underline that specifying fixed and variable costs in an appropriate and exhaustive way is a key step in developing a good business plan. While term *exhaustive* is related to selecting variables, term *appropriate* relates to initializing variables.

Initializing variables

This shortcoming deals with assigning inappropriate values to (some of) selected variables. For example, the values of payments, costs and income may not be realistic or even wrong, especially if the modelers are not familiar with the context of the analyzed business situation. Needless to say, such initializations would yield business recommendations that are not context-grounded.

Initializing variables is, for example, related to selecting variables (directly) and relating variables (indirectly). Ask, for example, weather the value of the fixed cost is appropriate in terms of its underlying fixed costs.

Ticket price (EUR)	30	
No of tables	22	?
No of guests	132	
No of waithers	4	?
Payments		
for restorant	1000	
for waithers	100	
for organizers	200	
for decoration	100	
for music	200	The number of waithers depends on the number of guests!
for food	800	For example, one waither per 20 guests
for drink	500	Payments for food and drink depend on the number of guests
for security	50	
Fixed costs	1350	
Variable costs	1600	Data in B22 and B24 are not used!
Total	**2950**	
Income		
from tickets	3960	
Profit	1010	

Screenshot 2. Fixed or variable costs

Relating variables

This shortcoming occurs when variables are wrongly or inappropriately related. In Screenshot 2, the variable cost is not expressed in terms of the number of participants. Another example, presented on Screenshot 3, is related to critical activity 2 mentioned in the Introduction. If students do not diversify different services offered (i.e. cleaning car, washing car, and cleaning & washing car) with respect to the number of served customers, and also combine such diversified payments and incomes, the analysis of the profit will be wrong or incomplete.

Profitability of car washing service	
PAYMENTS	
for running busines	1,000.00 €
for investment	300.00 €
for flat TAX rate	200.00 €
for workers	1,000.00 €
for water	200.00 €
for electicity	250.00 €
for marketing	150.00 €
TOTAL	**3,100.00 €**
Services	
S1: Cleaning inside	15.00 €
S2: Washing outside	10.00 €
S1 & S2	22.00 €

ELEMENTS	*VALUES*	
Service 1 (S1)	15.00 €	
Number of days per month	30	
Number of cars per day	4	PROFIT
INCOME	1,800.00 €	(1,300.00) €
ELEMENTS	*VALUES*	
Service 2 (S1)	10.00 €	
Number of days per month	25	
Number of cars per day	5	PROFIT
INCOME	1,250.00 €	(1,850.00) €
ELEMENTS	*VALUES*	
Service 2 (S1)	22.00 €	
Number of days per month	30	
Number of cars per day	5	PROFIT
INCOME	3,300.00 €	200.00 €

Screenshot 3. Relating variables

Discussion

Initializing variables reconsidered

The question of initializing variables again appears when several business scenarios are to be generated and compared (e.g. "What would the outcome under optimal, favorable and unfavorable market conditions be?"). The modelers thus should not only know what input variables are critical to their output variables, but also what values of these critical input variables should be used for different scenarios. These issues, which are relevant to the transition from evaluation to report, are connected with selecting, initializing and relating variables in the transition from real world problem statement to mathematical model. An example of the use of scenarios is given on Screenshot 4. Because the modeler's approach to her problem was disintegrated with respect to different services offered (see Screenshot 3), such a use of scenarios, though context-grounded, was useless concerning a business recommendation to propose.

Scenario Summary	Current Values:	bad	acceptable	good
Changing Cells:				
Service cost	15.00 €	20.00 €	15.00 €	12.00 €
No. of service provided	5	10	15	20
Result Cells:				
Income	75.00 €	200.00 €	225.00 €	240.00 €

Screenshot 4. Initializing variables

Reasons for the three shortcomings

Possible grounds for shortcomings in selecting and relating variables can be extrapolated from the literature. First, technology perceived as a master (see Galbraith, 2002) does not require everything to be specified. In other words, for some modelers technology may act in a smart way (even if the things are not clear to modelers who use it and they do not realize that). Second, because in the SOLO model (Biggs & Collins, 1982) person's understanding of a task progresses from single aspect (uni-structural response) to several, but disjoint, aspects (multi-structural response) to several, integrated aspects (relational response), some modelers may give multi-structural responses as evidenced on Screenshots 3 and 4.

The modelers' presentations of their solutions revealed that most of them had problems to understand the analyzed business context. Because of such problems, many students were concerned with the limitations of their models with respect to the detail richness and appropriateness of their input variables as well as the values assigned to them, which influenced the quality of selecting, initializing and relating variables.

Suggestions for further research

The modelers analyzed business situations with deterministic, non-optimization models, which required repeated calculations. But this was just a part of the landscape involving four types of models: deterministic with no optimization, deterministic with optimization, stochastic with no optimization, and stochastic with optimization. For this landscape with calculations, simulations, optimizations, and simulations with optimizations, selecting, initializing and relating variables may become selecting, initializing and relating modeling objects. Further studies may examine the following questions: “What are these modeling objects?” and “What reasons are likely to cause shortcomings in selecting, initializing and relating them?”

When using models, their results may be clear, but it may not be clear what initialization of variables to apply, what to infer when using models with such (repeatedly) changed data, and what to require for the analyzed business to improve it. Because of such metacognitive decisions, it was not surprising that making business recommendations that are both model- grounded and context-grounded was simply out of reach of most students in this study. Having realized that, the framework of Galbraith and Stillman (2006) may be extended with critical activities concerning the transition from evaluation to report. A refinement of this framework may also be needed for the above-listed activities regarding the transition from real world problem statement to mathematical model (see the Introduction). In the context of this study, choosing technology to automate application of formulae to multiple cases (Activity 7) is relevant to the former transition not the latter one. In general, a refinement of this framework may be undertaken to reflect different types of models and versatile technologies like Microsoft Excel and its add-ins.

Acknowledgement

This contribution resulted from the author’s work on projects 144032D and 144050A funded by the Serbian Ministry of Science.

References

Biggs, J. B. & Collins, K. F. (1982). *Evaluating the Quality of Learning: The SOLO Taxonomy*. New York: Academic Press.

Coles, S. & Rowley, J. (1996). Spreadsheet modelling for management decision making. *Industrial Management & Data Systems*, **96**, 7, 17-23.

Conway, D. & Ragsdale, C. (1997). Modeling optimization problems in the unstructured world of spreadsheets. *Omega*, **25**, 3, 313-322.

Crouch, R. & Haines, C. (2004). Mathematical modelling: transitions between the real world and the mathematical model. *International Journal of Mathematical Education in Science and Technology*, **35**, 2, 197-206.

Galbraith, P. (2002). Life wasn't meant to be easy: separating wheat from chaff in technology aided learning. *Proceedings of the 2nd International Conference on the Teaching of Mathematics at the Undergraduate Level.* Retrieved 1 April 2006 from: www.math.uoc.gr/~ictm2/Proceedings/invGal.pdf

Galbraith, P. & Stillman, G. (2001). Assumptions and context: Pursuing their role in modelling activity. In J. F. Matos, S. K. Houston, W. Blum, & S. P. Carreira (Eds.), *Mathematical modelling and mathematics education: Applications in science and technology* (pp. 317-327). Chichester: Horwood Publishing.

Galbraith, P. & Stillman, G. (2006). A framework for identifying student blockages during transitions in the modeling process. *Zentralblatt für Didaktik der Mathematik*, **38**, 2, 143-162.

Heys, C. (2008). Getting the best out of Excel. *Teaching Mathematics and its Applications*, **24**, 1, 48-52.

Kadijevich, Dj., Haapasalo, L. & Hvorecky, J. (2005). Using technology in applications and modeling. *Teaching Mathematics and its Applications,* **24**, 2/3, 114-122.

Keune, M. & Nenning, H. (2003). Modelling and spreadsheet calculation. In Q-X. Ye, W. Blum, K. Houston & Q. Jiang (Eds.), *Mathematical modelling in education and culture: ICTMA10* (pp. 101-110). Chichester, England: Horwood Publishing.

Parramore, K. (2007). Enlisting Excel**.** *Teaching Mathematics and its Applications*, **26**, 2, 73-78.

Teo, T. S. H. & Tan, M. (1999). Spreadsheet development and ‘what-if’ analysis: quantitative versus qualitative errors. *Accounting, Management & Information Technologies*, **9**, 3, 141-160.