BACHELOR STUDENTS’ SPREADSHEET SKILLS AND CONSEQUENCES FOR TEACHING IN BUSINESS SCHOOLS

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Abstract:
This paper reports on a study designed to enhance the understanding of bachelor students’ spreadsheet skills when they commence their studies at a business school. Such understanding is essential for designing an effective curriculum. The spreadsheet is still considered the most common decision support tool. Therefore, bachelor students should acquire spreadsheet modelling skills during their studies.

At the beginning of a mandatory course in business data processing, bachelor students were asked to hand in their answer to a spreadsheet task. The task was voluntary, and 31% of the students (N=117) handed in their model or an empty spreadsheet. The results showed that about 90% of the students lacked basic technical spreadsheet skills, and that they did not know how to structure a spreadsheet so that their model was useful for decision support.

The implications of our study is that business students need a course on principles of spreadsheet design and programming, but also that the teacher should start building the students’ conceptual understanding of the spreadsheet before any meaningful problem solving can occur.

Key words: Spreadsheet, teaching, decision support, spreadsheet modelling, spreadsheet skills, spreadsheet design principles, problem-based learning

1 INTRODUCTION

The purpose of this paper is to enhance the understanding of students’ spreadsheet skills when they commence their studies at a business school. Such understanding is essential for planning an effective curriculum.

The spreadsheet is considered an important tool to support decision makers when they analyse data and make decisions (Presthus, 2015; Madahar, 2011; Panko, 2006). Spreadsheets allow end users to take command of their programming needs. However, spreadsheets lack the structure of programming languages enforcing users to follow certain rules in order to avoid errors in specifications and formulas. Evidence exists that critical errors occur in spreadsheets applied in managerial business processes (Panko & Aurigemma, 2010; Morgan Chase, 2013). Furthermore, experience with spreadsheets does not seem to increase expertise considerably (Madahar, 2011).

Therefore, bachelor students should acquire spreadsheet modelling skills during their studies, that is, the students should be taught knowledge of spreadsheet design and programming principles, and they should be trained to apply the principles when developing spreadsheet models.

In order to enhance our understanding of how to plan the lectures and training in an introductory course in business data processing, we gave the bachelor students a spreadsheet task at the beginning of the course. The task was designed to elicit the students’ knowledge of spreadsheet modelling according to principles that are similar to principles of “good spreadsheet skills” applied at other business schools, see, for example, Frownfelter-Lohrke (2017).

The rest of this paper is organised as follows: In the next section, we motivate and position our study. Then we present our research design and procedures for data collection and analysis. In section three, we present our findings. In the final section, we summarise the findings and discuss implications for teaching.
spreadsheet design and programming. Limitations of the study are also discussed together with directions for further studies.

2 LITERATURE REVIEW

In this section, we explain essential concepts, position our study and present our research questions.

A spreadsheet is a large electronic grid sheet. It is easy to enter numbers and make the programme perform calculations, so that individuals with little knowledge of programming principles may use spreadsheets, for example for setting up budgets and calculating results. Even though the spreadsheet helps users avoid syntactic errors when entering formulas and applying functions, the spreadsheet does not support the users with regard to the structuring of the spreadsheet, the specification of variables and the entering of formulas that are programmed appropriately (see below). In other words, the spreadsheet does not support users with regard to representing and solving business problems so that the models are suited for considering alternative scenarios or for use by other individuals than the person who has developed the model.

As a consequence, there is evidence in the literature that critical errors occur in spreadsheets applied in managerial business processes (Panko & Aurigemma, 2010; Morgan Chase, 2013). From our contacts with business firms, we have an example of a model developed for evaluation of shipping investments. We detected that the model returned the wrong net present value when we proposed some changes to the model. The cause of the error was an exchange rate entered as a constant in just one of the formulas deep down in the model. There were no syntactic errors, and the users had not detected the error.

Furthermore, experience with spreadsheets does not seem to increase expertise considerably (Madahar, 2011). In his study of 686 managers and consultants’ spreadsheet use (Madahar, 2011, p. 117), 62.3% of the respondents reported that they had extensive experience with spreadsheets, but also that they considered they had only some expertise. 55% of the respondents did not have formal instruction.

There is a rich literature on the use of spreadsheets. Much of this literature concerns spreadsheet errors and the categorisation of spreadsheet errors (see, Powell, et al., 2008, for an overview). Most of the literature is descriptive. The purpose is to enhance the understanding of which types of errors occur in spreadsheets, and then – implicitly – also the cause of some errors. For example, Galetta et al. (1993), distinguish between domain errors and device errors. Domain errors refer to errors that are related to the application area (e.g., budgeting), while device errors are related to the application of the spreadsheet (e.g., wrong cell range in a formula). Panko and Halverson (1996) made a distinction between quantitative and qualitative errors. Quantitative errors are errors in the current version of the spreadsheet, whereas qualitative errors refer to risky practices that could lead to errors in subsequent versions (e.g., constants in formulas).

Some of studies attempt to understand the process of developing and debugging a spreadsheet model (Panko & Halverson, 1996; Panko, 1998, 2006). The purpose is to find out how the errors occur when developing a spreadsheet model.

Other studies attempt to evaluate the effects of training (Janvrin & Morrison, 1996; Kruck & Sheetz, 2006). These studies are closely related to prescriptive research, presenting guidelines for spreadsheet design and programming. In a recent paper, Frownfelter-Lorcke (2017) presents a plan for teaching spreadsheet design based on “principles of good design” by Kreye and Pendley (1998). Her students are required to complete three spreadsheet assignments in an iterative and repetitive process. According to the author, the students have acquired “good spreadsheet design skills and improved their basic Excel skills” after having completed the three assignments.

To the best of our knowledge, the studies investigating training and effects of training do not control for the students’ knowledge at the start of the training. We believe that understanding of the students’ previous knowledge and skills is important both when the effects of training are evaluated, and when the training is planned.

Our research is particularly related to the concern that spreadsheet skills do not seem to develop through experience (Madahar, 2011), that is, instruction and training are necessary. Since the spreadsheet is considered an important tool to support decision makers when they analyse data and make decisions
(Presthus, 2015; Madahar, 2011; Panko, 2006), it is important that business students learn how to handle a spreadsheet effectively during their studies. As responsible for an introductory course in spreadsheet design and programming, we are, therefore, concerned with the effective organisation of the course.

An essential element in planning a course is to adapt the course contents and the implementation of the course plan to the students’ knowledge. Our course is based on the principles of problem-based learning (PBL). PBL was developed by Barrows (1986) as a response to the criticism against courses with traditional lectures, in that they do not prepare the students for their future lives. This criticism against traditional lecturing originated in medical education, but has spread to other disciplines, such as economics (e.g., Fuglseth, Grønhaug & Jörnsten, 2016).

The primary goal of PBL is to enhance learning by requiring that students solve ill-structured, interdisciplinary problems. PBL is based on constructivist assumptions that knowledge is individually constructed and socially co-constructed from interaction with the environment. Since knowledge is an individual construction, knowledge cannot be transferred, but in interactions, we can test the degree to which our individual understandings are compatible (Lave & Wenger, 1991; Wenger, 1998; Savery & Duffy, 2001). The principles of PBL are often misunderstood so that students are presented with problems from the start of the course, and that the teacher plays a minimal role (e.g., Srinivasan et al., 2007). Barrows (1986, p. 484) emphasised, however, that PBL include an “active, teacher-guided exploration and evaluation of the problem using facilitation or tutorial skills, which directly activate the student’s prior knowledge, much of which may otherwise be beyond conscious recall”. Barrows (1986, p. 484) elaborated further on the teachers’ role as lecturer when it is necessary for the students to receive some initial information, “out of concern that the student must know some vocabulary and definitions, and have an overview of the subject before any meaningful problem-solving can occur”.

Thus, this paper is closely related to the paper by Frownfelter-Lorcke (2017), developing a spreadsheet course with problems of increasing complexity to be handled by the students. However, we extend her teaching method by enhancing our knowledge of the students’ spreadsheet skills before we plan our course with regard to lectures on design and programming principles. Frownfelter-Lorcke (2017) characterises her course as a course on design of spreadsheets. We prefer to distinguish between technical skills and design skills. Technical skills are related to the students’ ability to enter data and performing calculations. Design skills concern the students’ ability to structure and program the spreadsheet so that the models are easy to understand for others than the developer (i.e., transparent), and so that the models are suitable for analysis when assumptions are changed (i.e., dynamic). Thus, we formulated the following research questions for our study:

1. To what degree are bachelor students able to enter data and perform calculations in a spreadsheet using cell references and standard library functions?
2. To what degree are bachelor students able to design a spreadsheet model so that the model is easily understood by other users?
3. To what degree are bachelor students able to design a spreadsheet so that the model is suitable for analyses of changed assumptions and uncertainty?

The formulation of the research questions reflects our assumptions that most students are probably able to enter numbers into a spreadsheet and perform some calculations. We want, however, to enhance our understanding of whether the students are able to utilise the potential of spreadsheets to develop models that are transparent (research questions 2) and dynamic (research question 3). The research questions build on each other, that is, if the students do not possess basic technical spreadsheet skills, they are not able to build transparent and dynamic models.
3 RESEARCH DESIGN

In this section, we describe our research design and procedures.

3.1 Research strategy – descriptive design

In order to answer the research questions, we planned a descriptive design, that is, we wanted to provide a detailed description of the students’ spreadsheet skills at the start of our course. One possible research strategy would be to collect data by interviewing a sample of students. We considered, however, that we would have a more accurate representation of the students’ skills by inspecting their performance on a problem that had been designed to reveal relevant knowledge and skills.

We developed a budgeting assignment to be solved by students in a bachelor course in business data processing. The students were asked to assist a fellow student who was going to decide financially on his housing situation for his three years as a student. Two possible housing scenarios were presented:

- Renting an apartment for a monthly rent of NOK 5 000.
- Buying a three-bedroom apartment for NOK 3 500 000. The purchase price was to be financed by a long-term loan with a fixed interest rate of 2.5%. A one-time document tax, 2.5% of the purchase price, was to be paid at the time of buying. This tax would be paid cash. Two of the bedrooms were planned to be let out to fellow students for NOK 4 500 per room, ten months per year. The cost of insurance, property tax and municipal taxes was estimated to NOK 16 000 the first year, increasing with 1.5% each of the following years. After three years, the apartment was expected to be sold for NOK 3 700 000. However, 2.4% of the sales price was expected to be paid in selling expenses.

The assignment consisted of three tasks:

- In the first task, the students were required to develop cash-flow models for the two housing scenarios.
- In the second task, the students were asked to extend their models from three to five years because their friend contemplated to extend his studies to a master’s degree. The students were informed that the selling price for the three-bedroom apartment was NOK 3 850 000 after the fifth year, and that there would be no changes in the interest rate for the loan or the rate for the selling expenses.
- In the final task, we asked the students to advise their friend whether he should rent or buy an apartment.

The course on business data processing was placed in the third semester of the bachelor programme. Excel had then not been taught or used in other courses of the bachelor programme. In the first year of their study, the students had an introductory course in business economics. Thus, the domain of the assignment should be well-known to the students, so that our evaluation of the students’ spreadsheet skills could focus on the application of the device, cf. Galetta et al. (1993).

3.2 Procedures for data collection

Before the first meeting in the course, the students had been told to bring their PCs with MS Excel installed. The assignment was handed to all students present in the second part of the introductory lecture of the business data processing course. 383 students attended the course. The students were asked to solve the problem and send their Excel workbook by email to the teacher after class, that is, they had 45 minutes to solve the assignment.

The students were informed that the assignment was voluntary, that their performance had no influence on their grade, and that the purpose of the assignment was to improve our understanding of their spreadsheet skills so that we could adapt the course to the students’ knowledge and skills. We urged all students to send in their answers. Students who did not manage to solve the task – or just part of it – were asked to send an email explaining why they were not able to attach a spreadsheet model. As an incentive to participate, we announced that ten gift cards of NOK 1 000 would be randomly assigned to those who sent in their answers.
3.3 Procedures for data analysis

In our evaluation of the students’ skills, we distinguished between technical spreadsheet skills and design skills. The technical skills comprise evaluation of whether the students perform calculations in the spreadsheet that return the correct result, whether they use cell references, and the degree to which they use standard functions, for example the SUM() function instead of several plus-operations.

In order to evaluate the students’ design skills, we need a standard of comparison. Our standard of comparison is similar to the design principles applied by Frownfelter-Lorcke (2017, pp. 70-71), based on the advice from Kreie and Pendley (1998). Our principles are based on our knowledge of system development and programming principles, and our experience from developing decision support systems using spreadsheets for the user interface (partly documented in Fuglseth & Gronhaug, 2003; Fuglseth & Strandenes, 1997).

For this study, we have applied the principles of transparency and dynamics. These principles represent a subset of the principles we teach the students in our courses. In the following we give an abbreviated description of the principles, see Fuglseth, Håtuft and Johannessen (2011) for a detailed description of the principles:

**Transparency**

The principle of transparency reflects that a spreadsheet model shall be clearly laid out so that it is apparent what the model and the variables represent, and how the model may support the users in their decision processes.

Guidelines for modelling according to this principle are that all assumptions of the model must be visible so that they can be inspected by the user. Furthermore, results (outdata) and indata should be clearly separated, and data should be grouped into purposeful categories. Purposeful categories depend on the type of model. For a budgeting task, a purposeful grouping of indata may be the distinction between decision variables and non-controllable variables. For example, managers can decide on the price of their products, but they cannot determine the price of crude oil.

Another guideline pertaining to the principle of transparency, is that model variables should be thoroughly explained. For example, a label describing the price of a product should also contain the unit applied, for example, whether the price is for 1000 pieces.

**Dynamics**

The principle of dynamics reflects the characteristic of a spreadsheet model that the users can change the assumptions (indata), and that the consequences of the changes are immediately transmitted throughout the model. The principle implies that the users can study the effects of their changes through the intermediate results to the final results. In other words, the model should be designed so that it is suitable for exploration of changed assumptions and uncertainty through “What if” analyses.

The most essential guideline for implementation of this principle is closely related to basic technical skills and the principle of transparency. It says: formulas must only contain cell references, not constants. The only exception to this guideline is a constant that is considered a fixed element of a general calculation formula, such as the formula for calculation of percentages, for example that a cell contains the formula “= 1 + $B6”, where cell $B6 contains the rate.

Another guideline is that the designer should consider whether indata should be entered as time series data. For example, the price of a product may first be considered to be fixed, but it may be purposeful to allow not only changes of the price, but also different changes of the price over time.

We developed an evaluation form for scoring the answers. The form consisted of 25 statements that should be scored as true or false. The statements measured technical spreadsheet skills and certain aspects of the students’ design skills. Three experienced teaching assistants helped scoring the answers using the evaluation form with regard to the students’ technical skills. These results were coded and analysed in Excel. The authors then analysed the students’ spreadsheet models in order to evaluate the design skills, and in this process we elaborated on and extended the evaluation form.
4 FINDINGS

In this section, we present our findings. 117 students sent an email to the teacher. This means that 31% of the students attending the course, responded to our request for information about their spreadsheet skills. We do not know how many students were present at the first meeting. In the following, we present our analysis of these 117 responses.

4.1 Addressing research question 1

To what degree are bachelor students able to enter data and perform calculations in a spreadsheet using cell references and standard library functions?

Our results reveal that 28 of the 117 subjects, that is, 24%, did not attach a spreadsheet file to their email. These students explained in their emails that they had none or minimal experience with Excel and therefore were unable to create a spreadsheet.

Thus, we received 89 emails with a spreadsheet attached. Analysing these 89 spreadsheets, we found that nine contained only text and numeric values, that is, no calculations were performed in the spreadsheet. The values in some cells indicated that the authors of these nine models must have entered pre-calculated numbers into Excel. For example, the value of the variable “Dokumentavgift” is entered as a constant (see cell E6 in Figure 1 below), but that value involves the multiplication of the purchase price with the document tax. One student raised his hand while working on the assignment and asked for help to find the calculator in Windows so that he could perform the calculations he needed.

Figure 1 shows a typical example of the spreadsheet models we received in response to the first task. As illustrated in Figure 1, the students used constants extensively in their formulas. Furthermore, all the subjects who performed calculations in the spreadsheet, had errors in their calculations. In other words, there were no complete solutions. The errors were due to wrong input values in the formulas, variables not being included, and/or erroneous use of operators (+, -, /, *, ^) and parentheses. For example, in Figure 1 the subject has stated the assumption in row 1 that the payback time for the loan is 20 years. She has assumed that the apartment is sold after three years, but she has only included three years’ instalments of the buying price as expenses, that is, she has not taken into consideration that the rest of the loan has to be paid also, so the result is wrong. It is not possible to decide to which extent such errors are domain or device errors, but considering that the students are second-year students, we interpret most of such errors as device errors and errors due to the limited time to handle the assignment.

Only four of the 80 subjects who performed calculations in their spreadsheet, used absolute cell references, that is, they used $ signs to lock row and/or column references, when this was purposeful. The remaining 76 subjects used only relative cell references, which is the default way of referencing in Excel. For example, in Figure 1, instead of entering the interest rate, 2.5%, as a constant in the formula, the interest rate should have been entered as an assumption in a separate cell. Then, the student should have referred to this cell in her calculations using absolute references.

42 of the subjects used the SUM() function in Excel to summarise data. The remaining 38 who performed calculations, summarised data using only plus or minus signs in their formulas as illustrated in cell I18 in Figure 1. The SUM() function was the only standard function used in the students’ models. We had designed the assignment so that a complete solution required use of the NPV() and IF() functions. Since none of the students managed to hand in a complete solution, we are not able to state whether they are acquainted with the function library in Excel.
4.2 Addressing research question 2

To what degree are bachelor students able to design a spreadsheet model so that the model is easily understood by other users?

Referring to the principle of transparency, 76 of the 89 students did not enter explicitly the assumptions of their models. For example, in Figure 1 the interest rate is a hidden assumption. This means that users of the model cannot figure out the interest rate unless they inspect the formulas where the 2.5% interest rate has been used.

The remaining 13 of the 89 subjects specified at least some assumptions of their models explicitly. However, inspection of these subjects’ models indicates that the reason for the specification was mainly to keep track of all the assumptions in the assignment, not to enter the data as input values in their calculations. In Figure 1, for example, the subject has entered the term of the loan as part of a text in row A. Thus, the value “20” cannot be referred to in a formula.

By specifying their assumptions, these 13 subjects made their models easier to understand at a first glance, that is, their models indicated how the results had emerged. However, the structural design of the models...
varied a lot. Some structured their models with time-series variables as shown in Figure 1. Others had rather messy structures without the use of time-series variables, see Figure 2.

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<th></th>
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**Figure 2**  Example of a solution for one of the subjects. Data view at the top, formulas at the bottom

Only two of the 13 subjects used the assumption data as input to formulas, but even these two students did not do so consistently. For example, the student who handed in the model shown in Figure 2 had entered the document tax as a formula instead of entering the tax rate of 2,5% and then calculating the document tax in cell B14.

None of the subjects distinguished explicitly between indata and outdata in their models, and the grouping of variables were rather limited. 37 subjects had distinguished between the two housing scenarios and had also grouped variables as income vs expenses.

20 of the subjects did not label their variables. 69 of the 89 subjects used varying degrees of labels to describe data in their models. Examples of labels are “Megler” which was used to refer both to the rate used...
when calculating the fee to the house agent, and the amount to be paid to the agent. However, interpreting the findings, we have again to consider that the students had limited time for development of their models. Several subjects did not include the complex elements of the assignment in their solution, such as calculating the interest on the loan for each year. Thus, their formulas were rather simple and easy to understand. For those who did include calculations of the interest, the formulas were long and ill-structured, see for example cells G8 and H8 in Figure 1. The students did not consider to specify intermediate variables and perform complex calculations in several steps. For example, the model in Figure 1 would have benefitted from including a variable for calculation of “remaining debt” in connection with the calculation of the annual interest amount.

4.3 Addressing research question 3

To what degree are bachelor students able to design a spreadsheet so that the model is suitable for analyses of changed assumptions and uncertainty?

As illustrated in the above examples, none of the students were able to design a spreadsheet model according to the principle of transparency. Without following the guidelines for transparency, we cannot expect the students to develop a dynamic spreadsheet.

Even though some of the subjects presented their assumptions before calculating the results, only two students referenced the assumptions in their formulas, that is, they had references in the formulas instead of constants. The remaining subjects used more or less constants in their formulas, making the models static and irreversible to changed assumptions. This means that only two subjects managed to create a spreadsheet model that could be used to analyse changes in the assumptions of the housing scenarios with regard to variables such as cost of insurance, property tax and municipal taxes.

When the students did not specify all the assumptions of the assignment in separate indata cells, they made it very hard for themselves to extend the time horizon of the model. None of the students managed to extend their model from three to five years. If they had made their models fully dynamic, this extension could have been made simply by selecting the last year in the initial model and copying/dragging the formulas to two more columns.

5 DISCUSSION AND CONCLUSION

In this paper, we present the results from analysing bachelor students’ responses to an assignment that required the students to demonstrate technical spreadsheet skills and design skills. The purpose of the analysis was to help us evaluate the students’ spreadsheet skills before we finally planned the course contents and organisation of an introductory course in business data processing.

Even though there were many errors in the calculations in the spreadsheet files handed in, we have the impression that the students had understood the assignment tasks, so that the responses reflected the students’ spreadsheet skills in a valid way, cf. the distinction between domain errors and device errors (Galetta et al., 1993). With a response rate of 31%, we also believe that the results reflect the students’ spreadsheet skills adequately. We are aware that our “sample” is self-selected: The assignment was voluntary, and the students sending an email to the teacher with or without a spreadsheet model attached were not anonymous. However, with the NOK 1.000 gift cards, it is reasonable to assume that few students would refrain from doing the task because they felt that it was too easy.

The time allocated for handling the assignment was only 45 minutes. With more time to develop the models, some errors would no doubt have been avoided. We believe, however, that 45 minutes is enough time for students acquainted with the spreadsheet to demonstrate their technical skills and their design skills.

As expected, most of the students were able to enter numbers into spreadsheet cells and perform simple calculations. 68% of the students were aware that cell references can be used in formulas, but they still used constants extensively. Seemingly, they did not understand the advantages of using cell references instead of constants. Only 3% used absolute cell references. In other words, 97% did not know how to create a dynamic spreadsheet model. The responses then also showed that the students had not learnt how to design
a spreadsheet so that it is easy to understand by others than themselves, and so that it is suitable for decision support.

According to the principles of PBL (Barrows, 1986), the students’ responses showed that they need to develop a conceptual system for spreadsheet programming and principles. Consequently, the teachers must help the students build such concepts first in lectures, that is, draw the students’ attention to concepts such as constants and variables, distinctions between variables with one value and time-series variables, and distinctions between relative and absolute cell references. Then the teacher must help the students develop their conceptual understanding and skills in problem solving sessions of increasing complexity, preparing the students for real-life spreadsheet modelling. Each training session should be complemented by debriefing sessions discussing and challenging the students’ solutions.

The implications for our teaching is that we have become more aware that we need to explain concepts that we expected bachelor students to be well-acquainted with, for example from lectures in mathematics, such as constants and variables. Students without a basic introduction to spreadsheet programming do not seem to recognise such concepts in the spreadsheet setting.

The purpose of the present study was to get insights into the students’ previous knowledge and to improve our scoring manual. In an ongoing study, we have improved our design: He have included control variables, and we have extended the study with a compulsory assignment allowing us to compare the results from the first and the second assignment at the individual level. The purpose is to evaluate the effects of attending our course. In addition, we plan to conduct a study with managers pursuing an Executive MBA in order to enhance the understanding of experienced managers’ use and knowledge of spreadsheet design and programming.

We believe that the bachelor students at our business school are not very different from bachelor students at other business schools. Thus, we hope that our results from the present study may be useful for other teachers responsible for spreadsheet courses.

6 REFERENCES


