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Enhancing Accuracy and Modelling in Financial Mathematics Education Through CSCL

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Abstract

This paper explores the impact of using the Excel software package in teaching Financial Mathematics. The research aims to achieve more accurate results and facilitate a more comprehensive approach to solving complex computational problems. Additionally, the study examines how Excel influences the overall problem-solving process, particularly in analyzing solutions and interpreting financial models. The research was conducted with two groups of students: a control group and an experimental group. The control group followed a traditional problem-solving approach without computers, while the experimental group used Excel software. The teaching content focused on cash flows, specifically determining interest rates, calculating loan installments, determining cash flows' present and future value over various time intervals, and conducting a detailed analysis of potential alternative financial scenarios. The experimental group demonstrated significant improvement in problem-solving, especially in areas requiring complex financial formulas, multiple computational operations, and decision-making. The findings highlight the advantages of Excel's functionalities, such as formula automation and data visualization, which reduce computational complexity and allow greater emphasis on interpreting the results. These results align with contemporary educational methods based on Computer-Supported Collaborative Learning (CSCL).

Keywords: Financial Mathematics, Excel functions, CSCL, Educational Methods, Accuracy.

MSC2020: 97M30, 97U70

1. Introduction

Financial mathematics represents one of the key subjects linking mathematics and its application in real-world contexts. The field of finance is nearly inconceivable without the use of advanced mathematics. Financial mathematics plays a significant role in developing skills necessary to understand complex economic and financial processes. When combined with related disciplines such as optimization and operations research, it yields significant results.

The traditional approach to solving problems in financial mathematics faces several obstacles. One major challenge is the computational complexity involved, as real-world models often require dealing with large numbers and intricate calculations. While the classical approach is essential for developing the foundational structure of models, it does not always yield optimal results. Specifically, in the context of this study, the traditional method often leads to computational errors, which subsequently affect decision-making and the interpretation of results. Additionally, the

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complexity of formulas can hinder understanding and complicate their practical application, negatively impacting students' motivation to solve problems.

On the other hand, Microsoft Excel has emerged as one of the most popular tools for addressing various financial mathematics problems. Particularly when integrated with other tools like Python or MATLAB, Excel enables easy enhancement and adaptation of problems to higher levels. Its functionality in working with tables and advanced mathematical functions makes it highly applicable in practical scenarios and education for solving specific financial mathematics problems. A notable advantage of Excel is its ability to provide a tabular representation of problems, which is especially useful in dealing with cash flows. Features such as drag-and-drop, auto-fill, and cell anchoring significantly accelerate processes that, using traditional methods, would require much more time. This allows students to focus on the core aspects of tasks - understanding the problem's concept and analyzing the results - rather than on technical details.

Functions like PMT (payment value), PV (present value), FV (future value), RATE (interest), and NPER (time) facilitate the manipulation of cash flows in Excel. They are used to solve problems such as analyzing the time value of money (present/future value), financial planning for loans, determining repayment periods, and calculating different interest rates. Combined with visual representation capabilities, these functions offer a major advantage, as visualization improves the interpretation of conclusions and the analysis of the entire problem-solving process. For instance, Excel simplifies tasks such as analyzing the impact of interest rate changes on loan payments, comparing loan plans under different rates, and observing how loan payments, outstanding balances, and interest change with variations in input parameters.

Key elements of financial mathematics, various models, and numerous examples used in teaching are extensively covered in the literature.

2. Theoretical background

In recent years, Computer-Supported Collaborative Learning (CSCL) has gained significant popularity in educational processes, where computer technology plays a crucial role in shaping collaboration. The concept of CSCL has been explored since the 1990s, with numerous foundational studies demonstrating its positive impact on the quantity and quality of social interactions in teaching (Amigues & Agostinelli, 1992; Lamon et al., 1996; McConnell, 1994). Recent research, specifically in Serbia, has also found that CSCL methods lead to better outcomes in learning mathematics at the higher education level (Milenković & Vučićević, 2024).

Chen et al. (2018) concluded that the integration of CSCL positively affects skill development and knowledge acquisition among students. Similarly, D'Souza & Wood (2002) compared CSCL-based teaching with traditional methods, focusing on collaborative learning using tables, and reported significant differences in student outcomes and the benefits of applying CSCL. Gunawan et al. (2019) highlighted the advantages of CSCL environments in integrated science courses, noting that most students demonstrated excellent proficiency in using tools like MS Word, PowerPoint, and Excel. Goodyear et al. (2019) reviewed several important CSCL studies, emphasizing the need for improved research methodologies and innovative techniques, such as collaborative scripts and content visualization.

Excel is one of the most widely used tools for mathematical calculations, data analysis, and advanced functions. Comprehensive guidance on using Excel can be found in publications by Albright & Fox (2019), Benninga (2014), Guerrero & Guerrero (2019), and McFedries (2013). Zhang (2014) emphasized Excel's effectiveness in teaching financial concepts, preparing students for market demands, and its applications in analyzing financial statements, stock valuation, capital budgeting, and financial derivatives.

Lusardi (2019) addressed the global issue of financial illiteracy, even in some of the most developed financial markets. He designed three key questions to measure financial literacy, providing a benchmark for identifying gaps in understanding fundamental financial concepts.

Wagner (2015) examined how financial education affected a person's financial literacy score, as well as short- and long-term financial behaviors. He found that, in general, a financial education course positively affected long-term behaviors to a higher degree than short-term behaviors. Also, in the paper by Zhou et al. (2023), the results indicated that education significantly improved basic financial literacy and provided valuable insights into ways to enhance financial literacy in the broader population. Recently, a particular connection between young adults' general intelligence and financial literacy has been examined. The work by Gignac & Stevens (2024) showed a strong correlation between general intelligence and financial literacy (with a correlation coefficient of around 0.76), which is higher than previously reported. Additionally, attitude toward numbers and the need for cognition were found to be significant predictors of financial literacy, with attitude toward numbers having a unique predictive significance. The paper by Kumar et al. (2023) explored how digital financial literacy, financial autonomy, and impulsivity influenced financial decision-making and perceived financial well-being. The findings (Kumar et al., 2023) showed that skills and financial literacy directly impacted decision-making, while financial capability and autonomy played a key role as mediators, with impulsivity having no significant effect.

In Serbia, previous reports on teaching financial mathematics analyzed the shortcomings of traditional methods and proposed Excel functions to solve financial models effectively within the subject of Financial Mathematics (Vučićević, 2024).

3. Research question

The main research question of this study focuses on the impact of using the Excel software package in teaching Financial Mathematics to achieve more precise results, as well as its influence on enabling a more comprehensive approach to solving tasks that require complex calculations. Additionally, the study examines the effect of Excel usage on the complete problem-solving process, including the final analysis of solutions, the interpretation of financial models, and decision-making outcomes.

4. Methodology

4.1. Participants

Our study included 103 students from the Faculty of Science, University of Kragujevac, Kragujevac, Serbia. They were divided into two groups:

1. The control group consists of 55 mathematics and computer science students from the 2021/2022 academic year.
2. The experimental group consists of 48 mathematics and computer science students from the academic year 2023/2024.

4.2. Instruments & Procedures

In the control group, students studied the course material in a traditional classroom setting without using computers. The classical approach involved deriving formulas and performing calculations using basic calculators. Students could also engage in discussions about the problem-solving process, the formulas applied, and the solutions obtained. After obtaining the results, students analyzed the solutions to the models based on their manual calculations.

In the experimental group, the exercises were conducted in a computer lab using computers and students' collaboration. The materials were pre-prepared and included the same problems as those selected in the control group. The teaching process followed these steps: for a given topic, specifically cash flows, the models were first introduced, and the formulas were derived. Subsequently, the formulas were demonstrated in Excel, with a detailed interpretation of the variables and a mapping of the parameters to the variables in the formulas. Students worked individually but were grouped into teams of three or four members to encourage interaction and discussions about problem-solving, fostering an environment aligned with the CSCL learning approach.

During the sessions, both students and the instructor used Microsoft Excel. In the example presented (Fig. 1), students first determined interest rates in Excel using the "equalization rule" and then calculated the loan installment based on the problem's setup.

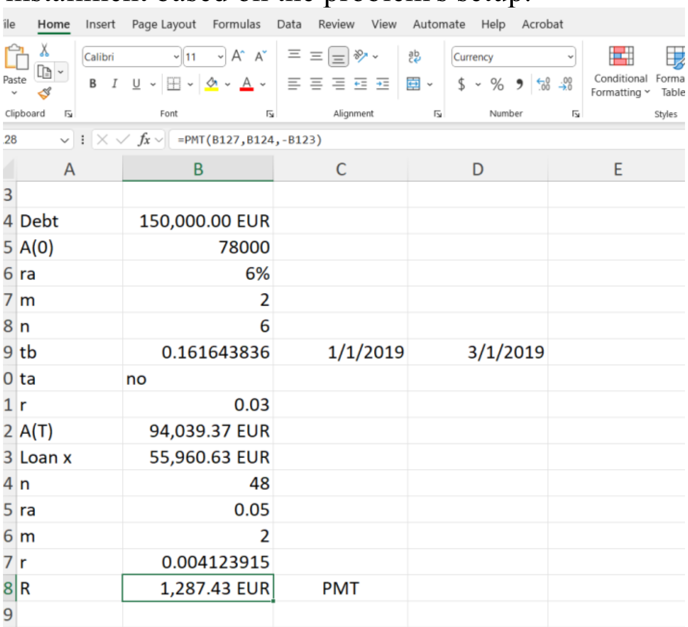


Fig. 1. Calculating Loan Installments Using Excel

At the end of the task, students discussed the conclusions from the results together, analyzed the solution, and considered alternative outcomes based on changes in the annual interest rate. They collaboratively discussed various possibilities for applying different models using the obtained solution.

In Financial Mathematics classes, students utilized formulas to calculate loan installments as well as the formula for the present value of money based on loan installments

$$A(T) = R\frac{1-(1+r)^{-n}}{r}, \qquad R = \frac{Z \cdot r}{1-(1+r)^{-n}}. \tag{1}$$

The Excel equivalents of these formulas are the PV (Present Value) and PMT (Payment Value) functions. Other functions, such as FV (Future Value) and Nper (Number of Periods), can also be utilized. Fig. 2 shows an example of these formulas, as demonstrated during the lectures.

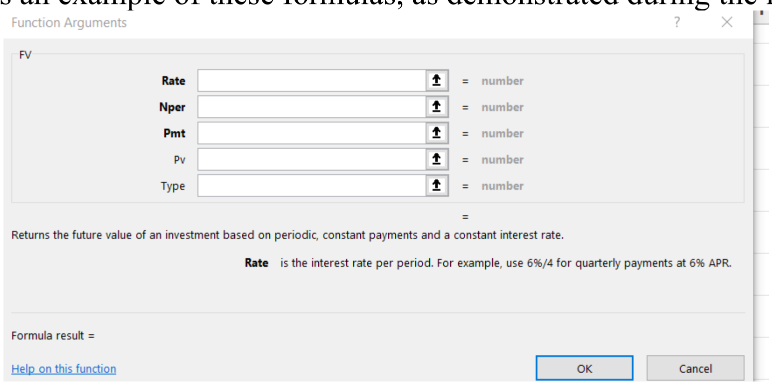
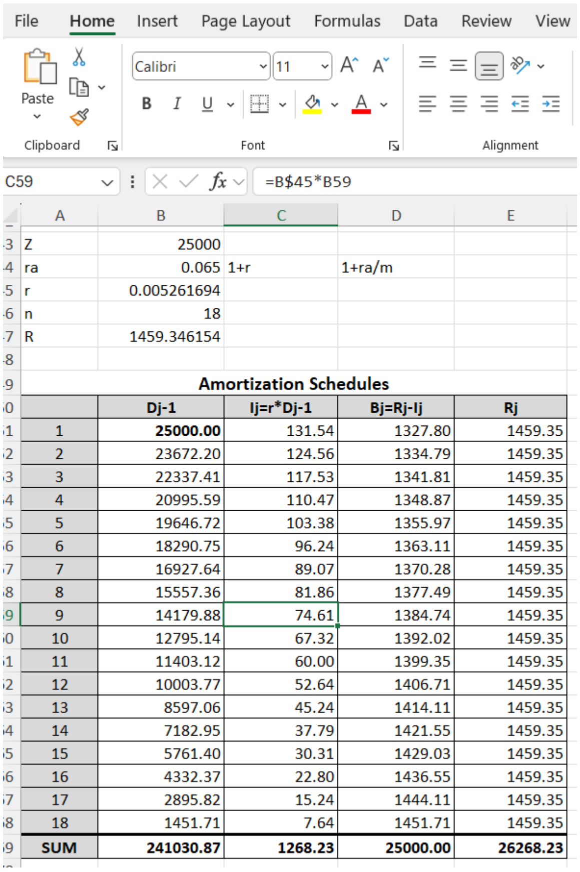


Fig. 2. Formulas used in Excel in Financial Mathematics classes.

The following example presents a task related to loan amortization, where the goal is to create a clear table containing information about the remaining debt, current interest, repayments, and loan installments (Fig. 3). The task can be solved using a table, where Excel offers significant advantages beyond just using formulas, as it also provides options for cell fixing and automation when filling in tables. Alternatively, the task can be solved manually by calculating all parameters, with students able to use the previously mentioned formulas and others as needed.

$$D_j = R\frac{1-(1+r)^{-(n-l)}}{r}, \quad I_{l+1} = R\left(1-(1+r)^{-(n-l)}\right), \quad B_{l+1} = R(1+r)^{-(n-l)}. \qquad (2)$$



Z	25000			
ra	0.065	1+r	1+ra/m	
r	0.005261694			
n	18			
R	1459.346154			

Amortization Schedules

	Dj-1	Ij=r*Dj-1	Bj=Rj-Ij	Rj
1	**25000.00**	131.54	1327.80	1459.35
2	23672.20	124.56	1334.79	1459.35
3	22337.41	117.53	1341.81	1459.35
4	20995.59	110.47	1348.87	1459.35
5	19646.72	103.38	1355.97	1459.35
6	18290.75	96.24	1363.11	1459.35
7	16927.64	89.07	1370.28	1459.35
8	15557.36	81.86	1377.49	1459.35
9	14179.88	74.61	1384.74	1459.35
10	12795.14	67.32	1392.02	1459.35
11	11403.12	60.00	1399.35	1459.35
12	10003.77	52.64	1406.71	1459.35
13	8597.06	45.24	1414.11	1459.35
14	7182.95	37.79	1421.55	1459.35
15	5761.40	30.31	1429.03	1459.35
16	4332.37	22.80	1436.55	1459.35
17	2895.82	15.24	1444.11	1459.35
18	1451.71	7.64	1451.71	1459.35
SUM	**241030.87**	**1268.23**	**25000.00**	**26268.23**

Fig. 3. Example of loan amortization.

4.3. Data Analysis

The statistical data analysis was conducted using the IBM SPSS Statistics 20 software package. Descriptive statistics were obtained, and normality tests, the Mann-Whitney test, and the Chi-square test of independence were used during the research.

5. Results

During the research planning, a pre-test was created for students in both groups to determine whether they approached the acquisition of content from Financial Mathematics with the same prior knowledge, which was necessary for understanding the subject matter. At the beginning of the semester, students solved four tasks: one related to the application of percentage calculations (8 points), another to the use of direct proportion (7 points), a third to the formula for the general term of an arithmetic progression, along with the determination of the initial term and the common difference of the sequence to find the requested term (10 points), and the last is related to determining the sum of a geometric sequence with a given number of terms (10 points).

Since the total score distribution on the pre-test did not follow a normal distribution for either the control group ($p = 0.04 < 0.05, df = 55$) or the experimental group ($p = 0.002 < 0.05, df =$

48), the total score distribution on the pre-test was compared using the Mann-Whitney test. As the differences were not statistically significant ($Z = -0537, p = 0.591$) in the scores achieved by the control group ($M = 21.49, SD = 9.92$) and the experimental group ($M = 22.79, SD = 8.52$), the research continued as planned.

After completing the lessons, students from both groups solved three tasks. As in the practical classes, students in the control group solved these tasks using paper, pencil, and a calculator, while students in the experimental group solved problems on a computer using Microsoft Excel. In Excel, students from the experimental group were able to use functions introduced during the lessons, along with creating appropriate variables beforehand. All three tasks were related to cash flows. The first task involved loan amortization, requiring students to create a loan plan, analyze the results, and discuss how the solution would be interpreted under different conditions. The second task involved cash flow with the determination of the present value of debt, combining several parts to determine the total amount of money, while the third task was a classic cash flow problem but with the determination of both the present and future values of cash flows for specified time intervals.

Analysis of the results from the first task (Fig. 4) reveals significant differences between the control and experimental groups in terms of accuracy in solving the task and drawing conclusions, i.e., decision-making based on the obtained results. To solve this example using the traditional approach, it was essential to create a table, and after all calculations, the crucial decision was to determine whether the loan was worth it for the consumer.

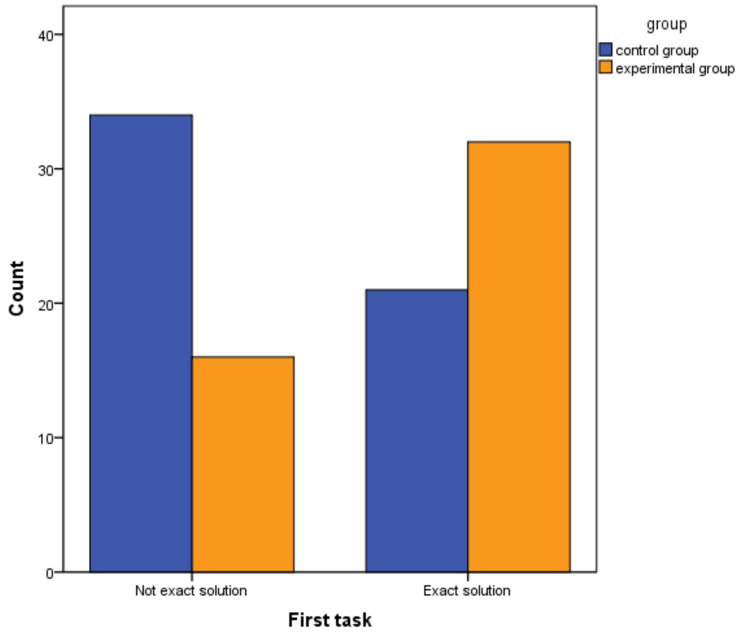


Fig. 4. Students' success in solving the first task on the test in both groups.

Unlike the control group, where only 21 out of 55 students (38.2%) successfully solved the task and made the appropriate decision; in the experimental group, 32 out of 48 students (66.67%) solved the task accurately and made the correct decision based on the obtained result. These differences in the number of correct and incorrect answers were statistically significant ($\chi^2 = 8.33, df = 1, p = 0.007 < 0.05$), leading to the conclusion that students in the experimental group were statistically significantly more successful in solving this problem.

A similar conclusion was reached for the second task. There was a significant difference in the accuracy of solving the problem between the two groups of students (Fig. 5). A careful analysis of the experimental group's work revealed that while they encountered difficulty with the complexity of formulas during the computational process, they overcame this challenge using Excel, which allowed for simple calculations and enabled them to focus on interpreting the results and making decisions for the corresponding models. The percentage of students in the control group who solved the task correctly was identical to that in the first task (38.2%) while the percentage of correct answers in the experimental group was nearly double compared to the control group (68.8%). Once again, the differences in the students' success rates between the two groups were statistically significant, with the experimental group performing significantly better ($\chi^2 = 9.60, df = 1, p = 0.004 < 0.05$). Therefore, students who used Excel in their work significantly improved their ability to determine cash flows, calculate the present value of debt, and combine multiple elements to determine the total sum of money.

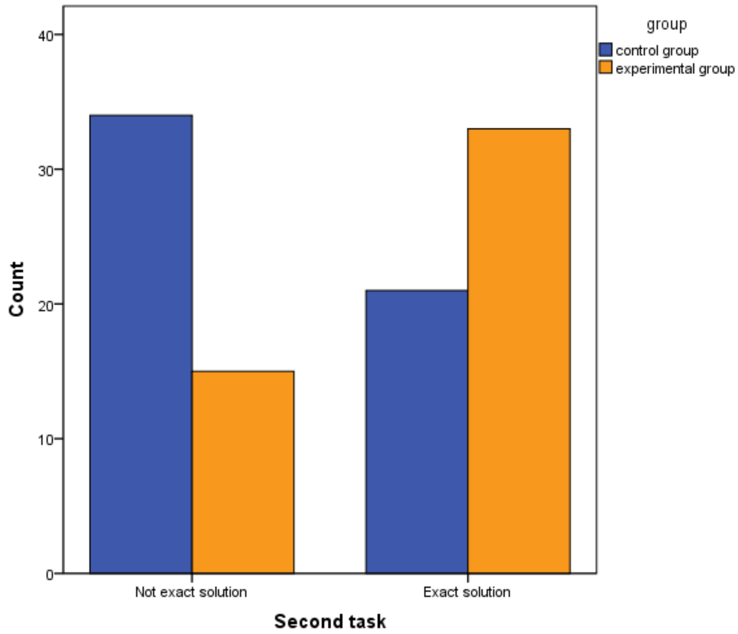


Fig. 5. Success of students from the two groups in solving the second task on the test.

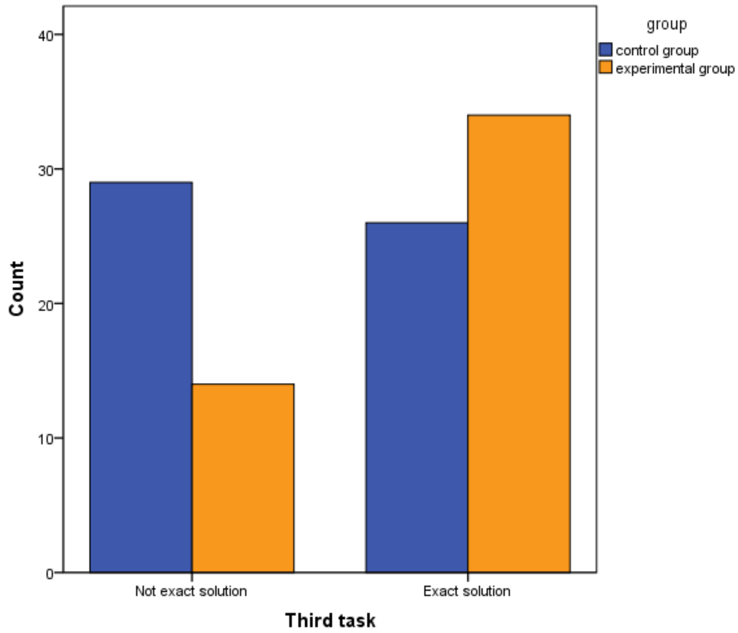


Fig. 6. Success of students from the two groups in solving the third task on the test.

In solving the third task (Fig. 6), a statistically significant difference in success rates between the two groups was observed ($\chi^2 = 4.92, df = 1, p = 0.007 < 0.05$). In the control group, almost half of the students (47.30%) solved the task successfully, while in the experimental group, the success rate was much higher, with an average of 70.80%. Analysis of the control group students' work revealed that although the formulas for solving this task (compared to the previous two tasks) were much simpler, difficulties arose in adapting the formulas to a specific time interval, where the formula's degree changes.

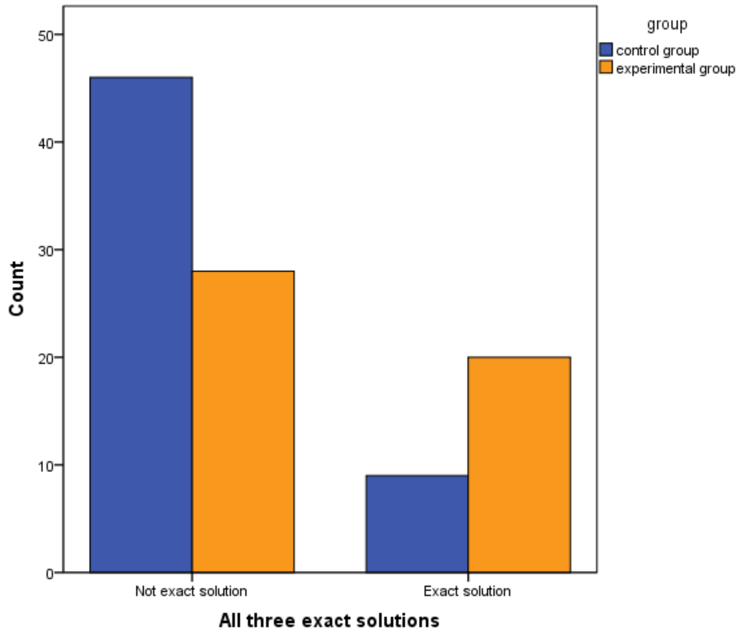


Fig. 7. Success of students from both groups in solving all three tasks on the test.

What was particularly interesting to us was the difference between the control and experimental groups when analyzing the overall success rate across all three tasks (Fig. 7). The differences were most noticeable here, as, unlike the experimental group, where 20 out of 48 students solved all three problems correctly; in the control group, only 9 out of 55 students managed to do so. The differences in the number of students who correctly solved all three tasks were statistically significant ($\chi^2 = 8.11, df = 1, p = 0.009 < 0.05$). We can conclude that the approach of solving problems using Excel was effective, as a greater number of students accurately performed the necessary calculations, correctly interpreted the results, and based their decisions on them.

6. Conclusion

The results of this research show that using Excel in Financial Mathematics teaching in a CSCL environment with students of Mathematics and Computer Science significantly contributes to the accuracy and efficiency of problem-solving, as well as the development of skills in analyzing results, interpreting them, and making decisions based on the given outcomes. Compared to traditional teaching methods, the experimental group demonstrated a higher success rate in solving tasks, particularly those requiring complex calculations and analytical approaches.

The use of Excel allowed students to focus on understanding the models and interpreting the results while the computational processes were automated, reducing the likelihood of calculation errors. Moreover, through practical examples and collaborative learning, students developed better competencies in applying mathematical models to real-world financial situations.

In conclusion, this study confirms that integrating software tools like Excel into the teaching process can significantly improve the quality of education in Financial Mathematics. This approach enables implementing more complex mathematical models and further connections with optimization techniques, potentially improving the models used in education and later in practical applications. Future research could focus on enhancing mathematical models in Financial

Mathematics and the simultaneous use of optimization techniques, emphasizing integrating more complex mathematical models into the field.

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Appendix

TEST

1. Ivan took out a loan of 24000 euros to purchase an apartment. The loan is amortized over 12 years with semi-annual equal annuities and a 5.5% annual interest rate, compounded semi-annually. After 15 paid annuities, the bank changed the loan terms, reducing the annual interest rate by 1%, and extended the repayment period by 2 years. Create an amortization plan for Ivan's loan. How much interest did Ivan pay in the last two years of loan repayment? How many years would the loan have been repaid if the monthly payment had been the same as after the change in terms?
2. When buying a car, the buyer immediately pays 3000 euros, while the remaining debt is repaid over the next 3 years at 250 euros per month at the end of each month. The seller charges an annual interest rate of 8% and capitalizes monthly. Determine:

   a) The price of the car if the entire payment was made immediately.

   b) The amount the buyer must pay in the 20th installment if they missed the first 19 payments and want to continue with the agreed terms.

   c) The amount the buyer must pay at the 15th installment if they wish to pay off the entire debt and have made all previous 14 payments on time.

3. Employees receive a subsidy from the bank at the beginning of each semester for the next 3 years: 15000 dinars for non-teaching staff and 25000 dinars for teaching staff. It is known that there are 25 non-teaching staff members and 120 teaching staff members. Determine the total amount of the deposits at the end of the third year and the present value of the invested amount. The interest rate is 4%, with monthly capitalization.