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AUTHORS: Abdullah ÖZKALE,Emel ÖZDEMİR ERDOĞAN

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Research Article

An instrumental genesis perspective on the students' using spreadsheet for the interest concept and calculations

Abdullah ÖZKALE¹, Emel ÖZDEMİR ERDOĞAN²

¹ Süleyman Demirel University, abduhahozkale@isparta.edu.tr
<https://orcid.org/0000-0003-1115-5924>

² Anadolu University, eerdogan@anadolu.edu.tr <https://orcid.org/0000-0003-2703-9530>

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Abstract – Spreadsheets are used in mathematics education because the software has the potential to organize data as well as examine the relationship between variables. Studies on the concept of interest show that students have difficulties in interpreting the effects of variables in interest formulas. This study aims to examine students' use of spreadsheets in terms of instrumental genesis in tasks that deal with the mathematical structure of the concept of interest. The research was carried out with eight students of the course of finance mathematics at a state university. Data obtained through screen recordings, clinical interviews, and observation notes were analyzed through thematic analysis. The results of the study show that the students could see the relationship between simple and compound interest through the sequential operations in spreadsheets, they can interpret the changes in values by estimating through multiple manipulations, and they understand the necessity of entering cell addresses.

Key words: interest, instrumental genesis, spreadsheets, instrumentation, instrumentalization

Introduction

The use of technology is one of the main research topics in the field of mathematics education (Miles, 2021). National Council of Teachers of Mathematics [NCTM] states that the learning environment should be designed to create a positive effect of technology use on learning (NCTM, 2015). Similarly, Van De Walle, et. al. (2015), emphasizes that the relationship between the tool and mathematical concepts should be set up for effective learning (Nobre et al., 2012; Van De Walle et al., 2015). Spreadsheets can be defined as a tool used in

teaching and learning environments as a common technology that is easy to access from different devices (Bernard & Senjayawati, 2019).

Spreadsheets are software that is frequently used in daily life, designed to organize, use and present data in tables. Spreadsheet are software that helps in tracing algebraic relationships between numeric data, with cell addresses and features such as cell formatting and creating formulas. In addition, it leads multiple data to be created and dynamic (Drier, 2001). Spreadsheets as one of the software used in mathematics teaching, is expressed as an effective learning material in NCTM standards (NCTM, 2015). Spreadsheets provide reasoning and practicing skills about concepts (Haspekian, 2014; Park et al., 2013). It is stated that it provides conceptual transitions in mathematics, which is a cumulative discipline, facilitates the calculation of multiple data, and reveals the relationship between variables in dynamic data groups (Abramovich, 2018; Mays, 2015). Spreadsheets have an intense relationship with mathematical concepts, especially financial operations, as well as reading data over tables and graphs. Accordingly, financial operations, in which percentage representations are used on the spreadsheet, can be considered as a research topic in mathematics education.

Percentage and interest calculations are the concepts handled in various levels of mathematics education. They are also included in curriculums (MEB, 2013; Pournara, 2013; Sugden et al., 2015; YÖK, 2020). In the literature, it is seen that students have some difficulties related to the concept of interest. According to the literature, the difficulties and misconceptions about simple and compound interest are briefly summarized in Table 1.

Table 1. Misconceptions and difficulties on the concept of interest

Mathematical structure	The inability to understand that simple interest is a linear function while compound interest is an exponential function
Calculating	Disregarding the increase of sequential principals in the transition from simple to compound interest Inability to calculate interest to intended values The inability to synchronize time Conversion mistakes on ratios The inability to reflect the relationships between ratio-percentage to calculations
Interpreting	Disregarding abnormal and unreal results and values The inability to compare the result of simple and compound interest calculations The inability to interpret the effects of variables on results

In studies in which percentage, rate, and interest types are handled together, there are some difficulties such as; the confusion between the calculations of interest types, the inability to perform meaningful calculations (Sugden & Miller, 2011), the inability to explain the interest calculations based on variables (Bakker et.al, 2006; Hoyles et.al, 2010; Hubbard et al., 2016) the inability to establish and interpret the relationship (Pournara, 2013). Besides, in the studies on the concept of interest, difficulties related to the variables of interest calculations are handled

as well. The maintain difficulties are such as; the difference in the number of periods and time synchronization of simple and compound interest calculations (Feng & Kwan, 2015), the incorrect use of interest rates in calculations (Chong, et al., 2015), the inability to detect abnormal values due to not following current interest parameters (Sugden & Miller, 2011), the inability to compare the differences of the parameters of the interest types (Marley-Payne & Dituri, 2019). This study aims to examine a learning process designed to handle interest calculations on the spreadsheet in terms of the instrumental genesis approach.

Theoretical Framework: Instrumental Genesis

Instrumental genesis theory is a framework in terms of examining the teaching process using the spreadsheet in the study. Instrumental genesis examines the relationship between the tool and the learning process, the techniques developed by the learners in the use of tools, and their conceptual development (Trouche, 2004). It is considered as the transformation from an artefact (tool) into an instrument. Instrumental genesis is handled in the following dimensions: instrumentalization and instrumentation. While an *artifact* is a material or abstract structure likely to be used for a given task; the *instrument* is a subjective process developed by the learner with the help of this tool. Besides, a schema is a solution created with an instrument (Drijvers & Trouche, 2008). While *instrumentalization* refers to the usage schemes that contribute to the transformation of the tool into an instrument, *instrumentation* emphasizes the conceptual schemes designed during the task (Özdemir Erdoğan, 2016). For example, spreadsheet, as an office program, can be a tool that is to be turned into an instrument using for generating solutions for financial calculations through conceptual schemes in terms of its functions and properties (Figure 1).

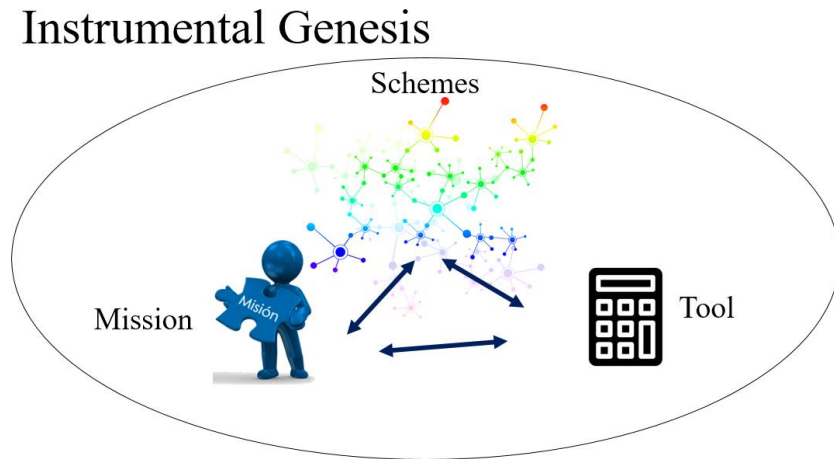


Figure 1. Transformation of a tool into an instrument (adapted from Drijvers & Trouche, 2008)

The *schemes* are formed by personalizing the features of the tool and can be revealed with the techniques presented by the learners (Drijvers et.al, 2013). Learners can make the same tool

into a different instrument in terms of their knowledge (Drijvers & Trouche, 2008). It is expected that the schemes that lead to the transformation of the tool into an instrument include solutions for the use of the tool and the mathematical background on which it is based (Özdemir Erdoğan, 2016). These schemes can be traced through instrumentalization and instrumentation.

While instrumentalization is users to personalize the tool and determine the mental paths that lead to the solution, instrumentation is the handling of the mathematical base of these paths and the relationships between the paths on the tool (Trouche, 2018). Instrumentation is a hybrid process that learners develop through the relationships between task and tool, which should be handled with instrumentalization beyond a mathematical development. (Trouche, 2018). It is emphasized to determine the conceptual components of the task and the personalized features used in the tool to examine the processes of instrumentalization and instrumentation (Gueudet & Trouche, 2011).

The Environment

Students of the Department of Banking and Finance, which is one of the programs carried out in vocational schools providing associate degree education in Turkey, work in financial institutions such as banks and insurance companies after their two-year education. Companies provide in-service training to their new employees that model their working processes. It is stated that the most important reason for this is the necessity of improving the competencies of the students in the field (Güvenç & Yücebalkan, 2017). People who work in the field of finance make almost all of their calculations with technological software. The schools offer courses that improve these aspects of students as well. Percentage and interest calculations are two main concepts frequently used in this department. Many calculations such as interest types, rates, loans presented in the product range of the banking are related to these concepts. In addition, the employees in the business should make correct calculations besides focusing on skills such as designing the calculations according to the customer's request at the optimum level, estimating and interpreting the changes based on the manipulations of different variables such as time, ratio, and principal amounts. The used technologies can make interpretation skills faster and more efficient as well as ease of calculation.

Purpose and research questions

This study aims to examine a learning process designed to handle interest calculations on the spreadsheet in terms of the instrumental genesis approach.

In this context, answers to the following research questions are handled:

1. How do students use spreadsheets functions and features in interest calculations?
2. What is the contribution of the use of spreadsheets to the students' development of the concept of interest?

Method

In this study, the case study method, which is one of the qualitative research approaches, was adopted. Case study is a method that answers the questions of why and how by examining in detail a situation, lesson or an activity (Yıldırım & Şimşek, 2008). Case study concerns with the process rather than the outcomes, the context of the case rather than the specific factors, and figuring out the facts rather than verifying them (Merriam & Grenier, 2019). Case study method was used for the study since it was aimed to examine the students' processes of converting the spreadsheet from a tool to an instrument.

Participants

The study was carried out with a group of 8 students among 89 who took the course of finance mathematics in the Department of Banking and Finance at a state university in the Western Mediterranean. In the study, the appropriate sampling method was used to reflect the environment taking into account the dispersion of their cognitive level and genders (Lehner, 1992). Akın, Ceylin, Didem, Doğuş, Hatice, Nurdan, Sema and Şengül, nicknames of the voluntary participants in the study. The students were familiar with the spreadsheet as an office program from their vocational courses, however, they used it the first time for the course of finance mathematics.

Data collection

In the study, four tasks were carried out in the spreadsheets. It was tried to obtain data that would reveal the skills and thoughts of the students in the process (Merriam & Grenier, 2019). Data collection tools of the study are; (1) screen recordings of students, (2) audio recordings of clinical interviews, and (3) observation notes taken by the researchers. Screen recordings were used as primary data collection tools to monitor students' skills in the tasks. The relationships between students' actions and thoughts were tried to be revealed through clinical interviews conducted during the tasks. The data were supported by researcher observation notes. It is aimed to increase the validity and reliability of the research data by using more than one data collection tool (Yıldırım & Şimşek, 2008). The Observation notes were taken in a structured form outlined in Table 6. This form was created on the main lines of instrumentalization and instrumentation, taking into account the dynamics of both instrumental genesis and the concept of interest. Researchers are also observers.

Process

(1) Preparation of the tasks: In the department of banking and finance, the concept of interest is handled in the fall semester of the first year within the course of finance mathematics. In the course, students use paper-pencil and functional calculators. Within the study, this concept is discussed in the Information Technology (IT) environment. The tasks were prepared in the spreadsheets taking into account the skills expressed in the literature along with the outcomes determined by the institution for the course (Hoyles, 2018; Pournara, 2013).

Accordingly, the tasks were built on four basic outcomes and instructions was presented to the students for each outcome.

Outcomes:

O1. Make simple interest and compound interest calculations with pencil-paper, calculator and spreadsheets.

O2. Provide transitions from simple interest to compound interest.

O3. Interpret variables of compound interest.

O4. Prepare compound interest applications on spreadsheets as well as monitor variable changes.

The tasks were prepared on the spreadsheet shown in Figure 2 and presented to the students as an Excel file.

E10	:	  	=S\$7*(1+B10)^\$C\$7			
	A	B	C	D	E	F
1	Kazanım: Bileşik faiz değişkenlerini yorumlar.					
2	Yönerge 3: Diğer değişkenleri sabit tutarak faiz oranındaki oynamaların toplam tutara ve aylık ödeme					
3	miktarlarına etkisini inceleyin.					
4	bileşik faiz					
5	toplam miktar = anapara*(1+faiz oranı)^dönem sayısı					
6	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
7	100.000,00 ₺	0,50%	60	34.885,02 ₺	134.885,02 ₺	2.248,08 ₺
8		0,75%			156.568,10 ₺	2.609,47 ₺
9		1%			181.669,67 ₺	3.027,83 ₺
10		1,50%			244.321,98 ₺	4.072,03 ₺
11						

Figure 2. An example from worksheets, Task 3

(2) Implementation steps: The implementation was carried out as an extracurricular activity, focusing on one of the outcomes for each week. Students performed these tasks using Excel 2013 on their equivalent computers. Table 2 indicates the calendar of the implementation during five weeks organized as two parts of 45 minutes each week.

Table 2. The Implementation Calendar

Process notes	
Week 0 (introducing spreadsheets)	• Deal with and try spreadsheet functions and features required for finance mathematics.
Week 1 (Outcome 1)	• Calculate simple interest and compound interest transactions on spreadsheets. • Check the calculations on the spreadsheets using a calculator and paper-pencil.
Week 2 (Outcome 2)	• Perform the transitions from simple to compound interest. • Trace the changes in multiple interest calculations using dynamics of spreadsheets
Week 3	• Interpreting the variables of compound interest.

(Outcome 3)	
Week 4	• Prepare compound interest practices on spreadsheets and monitor variable changes
(Outcome 4)	

As seen in Table 2, before the tasks, a short training was given to the students on the features of spreadsheets that they will benefit from in interest calculations. Then, in the first week, the students were asked to transfer the interest calculations they made in a paper-and-pencil environment to spreadsheet. In this task, the students were not guided about the features they should use. In the second task, it was aimed to examine the relationships between compound and simple interest calculations and the effects of the parameters. For this, students were provided with support where necessary by reflecting the teacher's worksheets. In the 3rd and 4th tasks focusing interpreting, it was tried to reflect the students' thoughts and images of the worksheets to be discussed in the classroom environment. Meanwhile, the researchers kept the communication in the classroom on the one hand, took observation notes and recorded the digital data at the end of the tasks.

Data Analysis

Thematic analysis was carried out in the study for data from screen recordings, clinical interviews and observation notes. The thematic analysis of the research was handled in two parts according to the instrumentalization and instrumentation that were dimensions of the instrumental genesis approach. Five themes given in Table 3 were created in terms of functions and features of spreadsheets, five themes of Ainley et al. (2005) given in Table 4 are related to the conceptual process. These analysis themes reveal the subjects' schemes defined within the framework of the instrumental genesis approach.

Table 3. The Instrumentalization Process

Themes	Tasks	Focal themes
1. Creating a formula - Create a formula using cell addresses - Perform function inputs from correct cells.	Task 1:	1,2,3
2. Using cell addresses - Provides dynamism of both cells and calculations.	Task 2:	1,2,3,4,5
3. Formatting Cells - Organize a readable working sheet with edits.	Task 3:	1,2,3,4,5
4. Fixing - Uses constant (\$) where necessary for drags.	Task 4:	1,2,3,4,5
5. Dragging - Use drag based on formulas, suitable for the pattern of given numbers instead of manual entries. - Use dragging in multi-manipulations. - Realize that dragging aims to do and trace maximum calculations as well as minimum manual entry.		

The analysis according to the themes obtained were carried out by the researchers together. When necessary, audio recordings and screenshots were re-examined, compared with the notes taken by the researchers, it was checked whether the data supported each other and data loss was tried to be kept to a minimum.

Table 4. The instrumentation process

Themes	Tasks	Focal themes
1. Constructing algebraic structures - Perform simple and compound interest calculations by creating formulas.	Task 1:	1,2,3
2. Explaining why - Explain the created formulas and spreadsheets properties under their mathematical background	Task 2:	1,2,3,4
3. Explaining the rule or relationship - Explain the relationship between interest calculations and their results. - Explain the effect of interest variables on results. - Estimate results according to interest rate variables. - Manipulate interest variables according to focal results.	Task 3:	1,2,3,4
4. Generalizing the process to many examples - Perform manipulations over the system established on spreadsheets.	Task 4:	1,2,3,4,5
5. Finding the unknown - Reach conclusions about the effects of the variables of simple and compound interest.		

Findings

In the first week of the research, the functions, formulas and other specified features of spreadsheets were introduced to the students in particular for the concept of interest. Although it was observed that the students were motivated, they had limited skills on the concept of interest, especially in the spreadsheets environment. The findings are handled under the sub-headings of each outcome in parallel with the implementation process for each week.

Calculate simple interest and compound interest on spreadsheets

In this first step, in which simple and compound interest calculations are expected to be made in the spreadsheets, students are reminded of simple and compound interest formulas. The first task is limited to creating cell address-based formulas and formatting them. It is observed that students who use calculators in previous lessons tend to manual inputs instead of creating formulas or using cell addresses for calculation (Figure 3).

anapara	faiz oranı	zaman (yıl)	faiz tutarı	toplam
32.000,00 ₺	1%	1	320,00 ₺	32.320,00 ₺

Figure 3. An example from Manuel inputs by Didem

The researcher did not intervene in this situation directly, the researcher oriented students to reasonable solutions. Formulating dependent variables such as the interest amount (I), the total amount (S) depended on the cell addresses was the focal target during the first lesson (Figure 4).

anapara	faiz oranı (aylık)	zaman (ay)	faiz tutarı	toplam
20.000,00 ₺	1%	12	2.400,00 ₺	22.400,00 ₺

Figure 4. An example for using cell address from a simple interest calculation by Şengül

The researcher supported students in formatting cells and formulas in the first week such as cell formatting and formula formation for using currency and financial values, by the researcher. In this process, the researcher gave instructions by showing the necessary technical steps on his own screen in a way that all students could see. These features were used by all students before the end of the first week. The researcher observed that the students preferred cell addresses instead of manual inputs after a few practices. Didem and Akın's statements shed light on their experiences on using cell addresses.

Didem: All my calculations would be correct if I created the cells correctly.

Akın: I wrote formulas in places (cells) where there are formulas, but I did not understand where else to write them.

While Didem describes the positive effect of using cell addresses on the accuracy of calculations, Akın tries to create schemes about which cells and variables should be used for cell addresses. It is seen that students have difficulty in using commas and dots while they can

easily perform currency formatting. Students stated that their previous spreadsheets and calculator experiences might have caused.

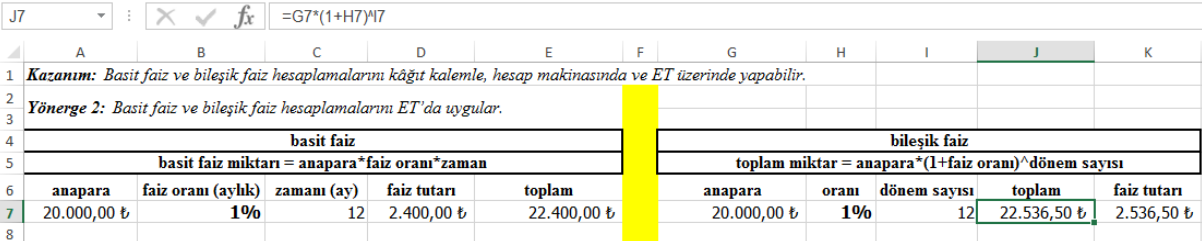
Doğuş: I already do this in the course of accounting. In fact, I have now emplaced it to quick access.

Akın: We were doing the opposite (using periods and commas) on the calculator. I could confuse frequently if I'm not careful.

Ceylin: Well, it gives an error when I put a dot! Why?

Ceylin falls with errors because she tries to write the dots for thousands that the spreadsheet separates automatically at the end of the calculations. It is monitored that the students do not have any difficulty in transferring the calculations of interest to the spreadsheets. All students write correct interest calculations besides, Nurdan and Sema successfully entered the formula based on cell address for the interest amount in compound interest calculations without any guidance (Figure 5).

$$I = P \times r \times t \quad S = P \times (1 + r)^{n*} \quad I = S - P$$

$$I \rightarrow = A7 * B7 \times C7/12 \quad S \rightarrow = G7 \times (1 + H7)^{I7} \quad I \rightarrow = J7 - G7$$


basit faiz					bileşik faiz				
basit faiz miktarı = anapara*faiz oranı*zaman					toplam miktar = anapara*(1+faiz oranı)^dönem sayısı				
anapara	faiz oranı (aylık)	zamanı (ay)	faiz tutarı	toplam	anapara	oranı	dönem sayısı	toplam	faiz tutarı
20.000,00 ₺	1%	12	2.400,00 ₺	22.400,00 ₺	20.000,00 ₺	1%	12	22.536,50 ₺	2.536,50 ₺

Figure 5. An example of using cell address for compound interest calculation by Nurdan

In Task 1, it is seen that the students have difficulties in writing the interest rate in the correct digit. Şengül, Nurdan, and Sema are able to write correctly, while five students (63%) have difficulty both in writing the interest rate, which was given ready-to-use as 0.95%, and using the percentage feature (Figure 6).

* P: Principal (initial value), r: Interest rate n: number of period of interest S: Total amount t: time (as years) I: Interest amount

basit faiz					bileşik faiz				
anapara	faiz oranı (aylık)	zamanı (ay)	faiz tutarı	toplam	anapara	dönem s.	faiz tutarı	toplam	aylık ödeme miktarı
20.000,00 ₺	1,00	12	240.000,00 ₺	260.000,00 ₺	20.000,00 ₺	12	60.436.824,49 ₺	60.456.824,49 ₺	5.038.068,71 ₺
35.000,00 ₺	0,01	12	4.200,00 ₺	39.200,00 ₺	20.000,00 ₺	13	117.890.807,76 ₺	117.890.807,76 ₺	9.068.523,67 ₺
100.000,00 ₺	0,95	100	9.500.000,00 ₺	9.600.000,00 ₺	20.000,00 ₺	14	229.867.075,12 ₺	229.887.075,12 ₺	16.420.505,37 ₺
70.000,00 ₺	0,10	40	280.000,00 ₺	350.000,00 ₺	20.000,00 ₺	15	448.259.796,49 ₺	448.279.796,49 ₺	29.885.319,77 ₺
					20.000,00 ₺	16	874.125.603,16 ₺	874.145.603,16 ₺	54.634.100,20 ₺
					20.000,00 ₺	17	1.704.563.926,16 ₺	1.704.583.926,16 ₺	100.269.642,72 ₺
					20.000,00 ₺	18	3.323.918.656,01 ₺	3.323.938.656,01 ₺	184.663.258,67 ₺
					20.000,00 ₺	19	6.481.660.379,21 ₺	6.481.680.379,21 ₺	341.141.072,59 ₺
					20.000,00 ₺	20	12.639.256.739,47 ₺	12.639.276.739,47 ₺	631.963.836,97 ₺

Figure 6. An example for using the wrong percentage for interest rate by Akın

In Task 1, it is observed that the students check the calculations by calculators they are used to. It is seen that this checking is not only for the results but also for the formulas that the students write cell addresses.

Sema: I am not sure if I write the percentage correctly, but my result shows that it is correct.

The transition from simple interest to compound interest

Students begin by creating a template for simple interest calculations and formatting cells in their worksheets. Then the students do the first-month calculation by entering data into the cells, they sustain the calculations sequentially by using dragging. In this task for Outcome 2, firstly, the equality of simple and compound interest calculations over the first month is handled. In the first step of Task 2, it is observed that half of the students (Hatice, Didem, Akın and Doğuş) entered the interest rate as numerical (manual) in the formula instead of cell addresses. In the task, the same interest rate is used for all calculations so the difference in entry data does not affect the results. But Didem realizes this situation at the end of the calculations (Figure 7).

Didem: I drag it, type the rate (interest rate) normally (manually), but it is fine. Probably, because it is not changed (the rate).

$$S \rightarrow = A5 + D5$$

$$S \rightarrow = B5 * (1 + C51)^{D12}$$

Y	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	bileşik faiz
1.	32.000,00 ₺	1%	1	320,00 ₺	32.320,00 ₺	
2	32.320,00 ₺		2	323,20 ₺	32.643,20 ₺	
3	32.643,20 ₺		3	326,43 ₺	32.969,63 ₺	
4	32.969,63 ₺		4	329,70 ₺	33.299,33 ₺	
5	33.299,33 ₺		5	332,99 ₺	33.632,32 ₺	
6	33.632,32 ₺		6	336,32 ₺	33.968,64 ₺	
7	33.968,64 ₺		7	339,69 ₺	34.308,33 ₺	
8	34.308,33 ₺		8	343,08 ₺	34.651,41 ₺	34.651,41 ₺

Figure 7. An example for using or not using cell addresses by Nurdan and Doğuş

Figure 8 shows the effect of fixing cells on the results in writing the targeted formula. Failure using fixing causes not occur the results or incorrect results in sub-rows. While Hatice forgets to use fixing, Ceylin and Şengül created the same formula for each row by manually updating the cell addresses according to the row, without using the fixing feature.

$I \rightarrow = B5 + E5$

$I \rightarrow = B12 * \$C\$5 * \$D\5

	A	B	C	D	E	F
1		Kazanım: Basit faizden bileşik faize geçişi ET üzerinde uygular.				
2		Yönerge 3 : Yeni toplam parayı kullanarak 1 aylık dönemlerdeki basit faizi hesaplayın ve bu işi istediğiniz bir döneme kadar devam ettirin.				
4	Y	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam
5	1.	32.000,00 ₺	1%	1	320,00 ₺	32.320,00 ₺
6						
7						
8						
9						

	A	B	C	D	E	F
1		Kazanım: Basit faizden bileşik faize geçişi ET üzerinde uygular.				
2		Yönerge 3 : Yeni toplam parayı kullanarak 1 aylık dönemlerdeki basit faizi hesaplayın ve bu işi istediğiniz bir döneme kadar devam ettirin.				
4	Y	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam
5	1.	32.000,00 ₺	1%	1	320,00 ₺	32.320,00 ₺
6		32.320,00 ₺			323,20 ₺	32.643,20 ₺
7		32.643,20 ₺			326,43 ₺	32.969,63 ₺
8		32.969,63 ₺			329,70 ₺	33.299,33 ₺
9		33.299,33 ₺			332,99 ₺	33.632,32 ₺
10		33.632,32 ₺			336,32 ₺	33.968,64 ₺
11		33.968,64 ₺			339,69 ₺	34.308,33 ₺
12		34.308,33 ₺			343,08 ₺	34.651,41 ₺
13						

Figure 8. An example for using or not using cell addresses by Hatice and Sema

In the third week, it is desired to indicate the equality of consecutive simple interest calculations to compound interest by using the fixing and dragging. In this process, while the students use the mentioned features of the spreadsheets in the first week, Şengül achieve the correct results by using the copy-pasting that she is familiar in her Office experiences. Ceylin rewrites the same values for each line. Although Hatice use the drag feature, she could not reach the correct result due to the error she makes on creating the formula.

Şengül: I may get confused about where to put the \$ in fixing, but I can finish the process by copy-pasting without needing dragging.

This task is designed for students to make sense of the relationship between simple and compound interest. The relationship between these concepts is not established over linear and exponential functions, taking into account the mathematics level of the students. Instead, it is enabled them to deduce that compound interest calculations consist of a combination of simple interest calculations by spreadsheets, calculators and paper-pencil on teacher instructions on the board (Figure 9).

Although the students accept that consecutive simple interest calculations and compound interest are equal, it is seen that they could not establish a relationship between the formulas. All of the students complete the task using cell addresses in the formulas and could generalize their calculations. Hatice and Nurdan's thoughts on Task 3 shed light on their worksheets including simple and compound interest calculations.

$$S \rightarrow = B5 * (1 + \$C\$5)^{D12}$$

H12

✕

✓

fx

=B5*(1+0,01)^8

	A	B	C	D	E	F	G	H
1		Kazanım: Basit faizden bileşik faize geçişi ET üzerinde uygular.						
2		Yönerge4: Son tahlilde bulduğunuz sonucu aynı oran ve anapara için bileşik						
3		faizle kıyaslayın.						
4	Y	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam		bileşik faiz
5	1.	32.000,00 ₺	1%	1	320,00 ₺	32.320,00 ₺		
6		32.320,00 ₺		2	323,20 ₺	32.643,20 ₺		
7		32.643,20 ₺		3	326,43 ₺	32.969,63 ₺		
8		32.969,63 ₺		4	329,70 ₺	33.299,33 ₺		
9		33.299,33 ₺		5	332,99 ₺	33.632,32 ₺		
10		33.632,32 ₺		6	336,32 ₺	33.968,64 ₺		
11		33.968,64 ₺		7	339,69 ₺	34.308,33 ₺		
12		34.308,33 ₺		8	343,08 ₺	34.651,41 ₺		34.651,41 ₺
13								

Figure 9. Comparison of consecutive simple and compound interest results by Didem

Nurdan: Compound interest is equal to successive calculations (on simple interest) but I cannot explain it by formula. ... I realize that compound interest calculations would be higher. Because although there is a calculation (in simple interest calculations), in the compound interest calculations, there are calculations as much as the number of periods.

Hatice: I have not known where the formula came from, I couldn't understand it now either. But dragging (successive calculations) makes it clear what compound interest is. ...I understand that money (capital) is reworked every month (period) in compound interest. This causes the last money (total amount) to rise.

Interpreting compound interest variables

In Task 3, the students are first asked whether they followed the current interest rates and other variables (for example, what would be the current interest rates for a loan of 100000 TL and the total amount of a 10-year loan?). It is observed that the students do not have sufficient information or experiences on them. A couple of students could not perceive unsuitable (too high) values in their compound interest calculations. During the task, the current interest rates are indicated on the websites of several banks and discussed with the students. After this process, students are asked to provide manipulation of compound interest variables (principal, interest rate, and time) with appropriate dragging operations. In this way, the effects of the variables are examined. Examples of worksheets created by students in this process are presented in Figures 10-12.

$$M = S/n^{\dagger}$$

$$S \rightarrow = A10 * (1 + \$B\$7)^{\$C\$7}$$

$$M \rightarrow = E7/\$C\$7$$

[†] M: Monthly payment

E10 : ☐ ☒ f_x =A10*(1+\$B\$7)^\$C\$7

	A	B	C	D	E	F
1	Kazanım: Bileşik faiz değişkenlerini yorumlar.					
2	Yönerge 2: Diğer değişkenleri sabit tutarak anaparadaki oynamaların toplam tutara ve aylık ödeme miktarlarına etkisini inceleyin.					
4	bileşik faiz					
5	toplam miktar = anapara*(1+faiz oranı)^dönem sayısı					
6	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
7	100.000,00 ₺	1,05%	60	87.145,36 ₺	187.145,36 ₺	3.119,09 ₺
8	120.000,00 ₺			104.574,44 ₺	224.574,44 ₺	3.742,91 ₺
9	130.000,00 ₺			113.288,97 ₺	243.288,97 ₺	4.054,82 ₺
10	150.000,00 ₺			130.718,04 ₺	280.718,04 ₺	4.678,63 ₺

Figure 10. The effect of changing of interest rate on compound interest results by Ceylin

$$S \rightarrow = \$A\$10 * (1 + B10)^{\wedge} \$C\$7$$

E10 : ☐ ☒ f_x =\$A\$7*(1+B10)^\$C\$7

	A	B	C	D	E	F
1	Kazanım: Bileşik faiz değişkenlerini yorumlar.					
2	Yönerge 3: Diğer değişkenleri sabit tutarak faiz oranındaki oynamaların toplam tutara ve aylık ödeme miktarlarına etkisini inceleyin.					
4	bileşik faiz					
5	toplam miktar = anapara*(1+faiz oranı)^dönem sayısı					
6	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
7	100.000,00 ₺	0,50%	60	34.885,02 ₺	134.885,02 ₺	2.248,08 ₺
8		0,75%			156.568,10 ₺	2.609,47 ₺
9		1%			181.669,67 ₺	3.027,83 ₺
10		1,50%			244.321,98 ₺	4.072,03 ₺

Figure 11. The effect of changing of interest rate on compound interest results by Didem

$$M \rightarrow = E8 / \$C\$7$$

F8 : ☐ ☒ f_x =E8/\$C\$7

	A	B	C	D	E	F
1	Kazanım: Bileşik faiz değişkenlerini yorumlar.					
2	Yönerge 3: Diğer değişkenleri sabit tutarak faiz oranındaki oynamaların toplam tutara ve aylık ödeme miktarlarına etkisini inceleyin.					
4	bileşik faiz					
5	toplam miktar = anapara*(1+faiz oranı)^dönem sayısı					
6	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
7	100.000,00 ₺	1,00%	60	81.669,67 ₺	181.669,67 ₺	3.027,83 ₺
8		10,00%			30.448.163,95 ₺	507.469,40 ₺

Figure 12. The effect of changing periods on compound interest results by Nurdan

In this process, the students realize that the increase of the principal is reflected in the total amount, interest amount, and monthly payments. While they understand that rising the number of periods increases the total amount, they have difficulty in making sense of the decrease in monthly payments. A couple of quotes from students' interviews explain this situation.

Şengül: It's a bit complicated! We cannot predict exactly which one (variable) will affect how. There are already so many cells (variables) that it seems difficult to set them all and determine the total amount or monthly payment.

Akın: ...but how do we know, teacher, does it increase or decrease (the total amount)? I think when the principal and interest rate increase payment (total) increases, but if the number of periods increases, I don't understand how total payment decreases!

Ceylin: I tried 0.5% (interest rate), it comes out 134000 (total amount), I write 1% and it comes out 181000. Isn't that too much, sir?

Didem: How big is the difference between 1% and 10%? Which rate is close to the rate of the banks?

One reason why students have difficulty interpreting the variables in compound interest calculations is a large number of variables. This situation is reflected in Şengül's statement. In addition, after the total amount is found, other results such as monthly payment play a role in decision-making for loans. From this point of view, it is seen that the students could refer a mathematical meaning to the manipulations of one variable by fixing the others, but they could not make the correct calculations for intended results. For example, a monthly payment of 2000 TL is requested for a loan but the manipulations for this adjustment cannot be formulated. Nevertheless, considering the statements of Ceylin and Didem, it is seen that the effects of the interest rates on the results cause surprise.

It is determined that a few problems continue in the use of spreadsheets during the implementation of the task. It is observed that Hatice's mistakes in formatting cells, dragging, and fixing lead to incalculable situations rather than wrong results (Figure 13). However, Hatice realizes her mistakes and makes the necessary arrangements.

Hatice: Sure! I forget to fix it while dragging. ...yes, I guess I do not convert it to TL (meaning formatting cells for currency), that's why.

$$M \rightarrow = E8/C8$$

	A	B	C	D	E	F
1	Kazanım: Bileşik faiz değişkenlerini yorumlar.					
2	Yönerge 2: Diğer değişkenleri sabit tutarak anaparadaki değişimlerin toplam tutara ve aylık ödeme miktarlarına etkisini inceleyin.					
3	bileşik faiz					
4	toplam miktar = anapara*(1+faiz oranı)^dönem sayısı					
5	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
6	100.000,00 ₺	1,05%	60	87.145,36 ₺	187.145,36 ₺	3.119,09 ₺
7	120000	10,5%	60	87.145,36 ₺	120.000,00 ₺	#SAYI/0!

Figure 13. Realizing the mathematical mistakes by Hatice

However, Doğuş, who completes his calculations with formulas using cell addresses, obtains a big large value that is not suitable for the problem situation due to the mistake he makes regarding the writing of the interest rate (typing 10.5% instead of 1.05%). In the interview, it is seen that Doğuş does not pay attention to this value and does not feel the need to verify the results.

Doğuş: What kind of mistake? (he does not think the results are abnormal). .. but I do not make any mistakes, I write the same in calculations.

...hmm! Of course, the monthly payment would not be 500,000 TL! Do I make a mistake in the formula?

..no, I do not notice that (he's talking about the mistake on the interest rate)

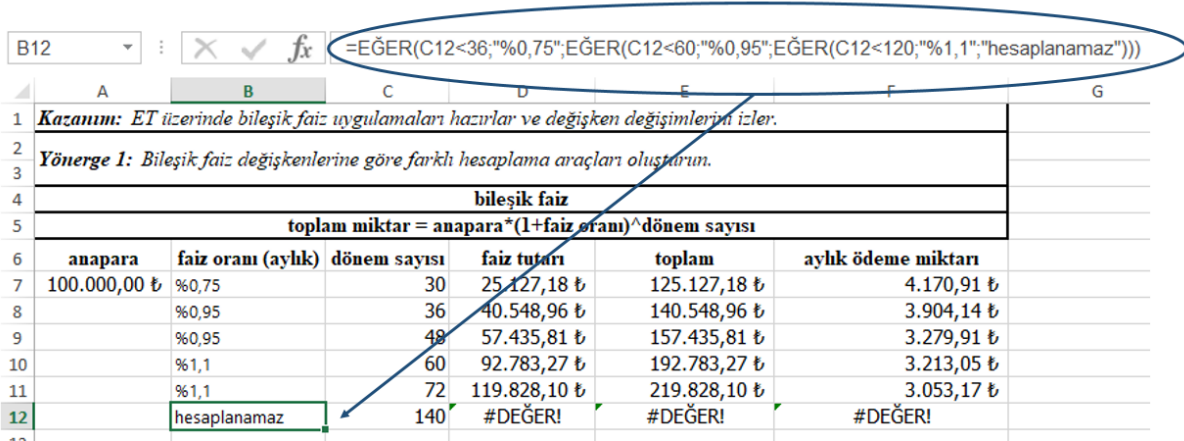
Preparing practices on compound interest on spreadsheets and monitoring variable changes

In Task 4, the last part of the study, students are asked to build up intended calculations on compound interest by the variables. In the regulations, it is requested that the results be harmonized with current values and the policies followed by the banks using the =if function. The policies are limited to the number of periods and the related changes in the interest rate. When the students need support regarding the use of = if function, the researcher guides them by sharing his screen. In Task 4, first, the effect of the number of periods and changing of interest rate in the compound interest calculations are handled. Hatice selects the wrong cell besides does mistakes on fixing. Sema reflects the interest policy manually on her worksheet without using =if function. Even then, Sema makes appropriate analyses and states that the increase of the number of periods reduces the monthly payment amount while increasing the total amount too much. Figure 14 shows that Doğuş limits the number of periods to 120 months and performs changes on the number of periods and interest rates in his worksheet. It is observed that Doğuş, Nurdan, Sema and Didem pay attention to both the interest policies and regarding

the change of interest rates over the duration of time. According to Doğuş's statements, it can be seen that he improves to both building up effective worksheets by functions and features of spreadsheets and interpreting the variables of interest.

- Sema: It is too long (typing =if function). I would definitely do it wrong.
High-interest rates increase everything (the total amount and monthly payment amount) so the number of periods should be as short as possible.
...of course, it increases a little bit (he talks about the increase in monthly payments when the period is shortened). But as I said, it depends on the interest rate.
- Doğuş: Now, when I write the formula (= if) as you do, I bring dynamism to the interest rate. I do not need to change it manually.
Yeah. I saw it in a bank's calculation engine. I got it from there. the interest rate can be 120 months maximal (number of periods).
Extending the duration increases both the interest rate and the total (amount).

$r \rightarrow = \text{if}(C12 < 36; \%0,75; \text{if}(C12 < 60; \%0,95; \text{if}(C12 < 120; \%1,1; \text{"uncountable"})))$



bileşik faiz						
toplam miktar = anapara*(1+faiz oranı)^dönem sayısı						
	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
7	100.000,00 ₺	%0,75	30	25.127,18 ₺	125.127,18 ₺	4.170,91 ₺
8		%0,95	36	40.548,96 ₺	140.548,96 ₺	3.904,14 ₺
9		%0,95	48	57.435,81 ₺	157.435,81 ₺	3.279,91 ₺
10		%1,1	60	92.783,27 ₺	192.783,27 ₺	3.213,05 ₺
11		%1,1	72	119.828,10 ₺	219.828,10 ₺	3.053,17 ₺
12		hesaplanamaz	140	#DEĞER!	#DEĞER!	#DEĞER!

Figure 14. Typing =if function for current interest rate policies by Doğuş

Considering the interest rates in Figure 14, Doğuş develops an understanding of the impact of changes in interest rates. While Doğuş is able not to notice the abnormal values in Task 3, he can interpret the effect of the 0.05% change in the interest rate on the total amount in Task 4. The researcher stated that the strategy that non-target variables are kept constant may be useful for examining the effect of target variables. Figure 15 shows Nurdan's strategy of fixing the total money. Nurdan develops a suitable formulation by removing the principal from the compound interest formula. According to the formula, the principal and monthly payment amounts change regarding the total amount.

$$P = S * (1 + r)^{-n}$$

$$P \rightarrow = \$E\$7 * (1 + B7)^n - C7$$

	A	B		D	E	F
1	Kazanım: ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izler.					
2	Yönerge 1: Bileşik faiz değişkenlerine göre farklı hesaplama araçları oluşturun.					
3						
4	bileşik faiz					
5	toplam miktar = anapara*(1+faiz oranı)^dönem sayısı					
6	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
7	95.902,43 ₺	%0,75	30	24.097,57 ₺	120.000,00 ₺	4.000,00 ₺
8	85.379,50 ₺	%0,95	36	34.620,50 ₺		3.333,33 ₺
9	76.221,54 ₺	%0,95	48	43.778,46 ₺		2.500,00 ₺
10	62.246,07 ₺	%1,1	60	57.753,93 ₺		2.000,00 ₺
11	54.588,11 ₺	%1,1	72	65.411,89 ₺		1.666,67 ₺

Figure 15. Keeping the total amount constant in compound interest calculations by Nurdan

Nurdan: The total amount does not change, but the principal decreases when the monthly payment amount decreases. I would not because the interest rate is higher.

Considering Nurdan's explanations, it is seen that she can interpret the results of the changes through correct calculations as well as explain the intended changes of the variables. Sema, the other student who could keep the total amount constant, keep the monthly payment amount constant to 2000 TL as well. She also follows the changes of the principals, interest amounts and total amount in the manipulations she carried out in accordance with the interest policies (Figure 16).

Sema: I keep the monthly payment constant, for this, I use the total money divided by the number of periods. Of course, firstly, I find the formula for the total amount then I drag the number of periods. Then I drag the sum and interest amount. I did so.

In other words, both (principal and total amount) are always increasing, I don't understand how they affect the monthly payment.

Sema explains how she uses the formulas on the spreadsheet besides, she expresses the mathematical structure of them. But it is seen that Sema has difficulty in explaining the relationship among monthly payment, total amount and principal. Nurdan, Doğuş and Didem could not create a formula to keep the monthly payment amount constant, but to find the closest calculations to constant monthly payment (2000 TL), they manipulate the values of principals and periods together. One of them, Nurdan's worksheet for this task is indicated in Figure 17.

$$P \rightarrow = E6 * (1 + B6)^n - C6 \quad I \rightarrow = E6 - A6 \quad S \rightarrow = \$F\$6 * C6$$

E7 :   $=\$F\$7*\$C7$

	A	B	C	D	E	F
1	Kazanım: ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izler.					
2	Yönerge 1: Bileşik faiz değişkenlerine göre farklı hesaplama araçları oluşturun.					
3						
4	bileşik faiz					
5	toplam miktar = anapara*(1+faiz oranı)^dönem sayısı					
6	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
7	67.033,40 ₺	%0,95	58	48.966,60 ₺	116.000,00 ₺	2.000,00 ₺
8	67.547,45 ₺	%0,95	59	50.452,55 ₺	118.000,00 ₺	
9	62.246,07 ₺	%1,1	60	57.753,93 ₺	120.000,00 ₺	
10	62.594,96 ₺	%1,1	61	59.405,04 ₺	122.000,00 ₺	
11	62.928,89 ₺	%1,1	62	61.071,11 ₺	124.000,00 ₺	
12	63.248,14 ₺	%1,1	63	62.751,86 ₺	126.000,00 ₺	
13	63.552,99 ₺	%1,1	64	64.447,01 ₺	128.000,00 ₺	

Figure 16. Keeping the total amount constant in compound interest calculations by Nurdan

	A	B	C	D	E	F
1	Kazanım: ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izler.					
2	Yönerge 1: Bileşik faiz değişkenlerine göre farklı hesaplama araçları oluşturun.					
3						
4	bileşik faiz					
5	toplam miktar = anapara*(1+faiz oranı)^dönem sayısı					
6	anapara	faiz oranı (aylık)	dönem sayısı	faiz tutarı	toplam	aylık ödeme miktarı
7	100.000,00 ₺	%0,75	30	25.127,18 ₺	125.127,18 ₺	4.170,91 ₺
8	100.000,00 ₺	%0,95	36	32.797,44 ₺	132.797,44 ₺	3.688,82 ₺
9	100.000,00 ₺	%0,95	48	32.797,44 ₺	132.797,44 ₺	2.766,61 ₺
10	100.000,00 ₺	%1,1	60	38.846,41 ₺	138.846,41 ₺	2.314,11 ₺
11	100.000,00 ₺	%1,1	62	38.846,41 ₺	138.846,41 ₺	2.239,46 ₺
12	100.000,00 ₺	%1,1	65	38.846,41 ₺	138.846,41 ₺	2.136,10 ₺
13	100.000,00 ₺	%1,1	66	38.846,41 ₺	138.846,41 ₺	2.103,73 ₺
14	100.000,00 ₺	%1,1	67	38.846,41 ₺	138.846,41 ₺	2.072,33 ₺
15	100.000,00 ₺	%1,1	68	38.846,41 ₺	138.846,41 ₺	2.041,86 ₺
16	100.000,00 ₺	%1,1	69	38.846,41 ₺	138.846,41 ₺	2.012,27 ₺
17	100.000,00 ₺	%1,1	70	38.846,41 ₺	138.846,41 ₺	1.983,52 ₺
18	100.500,00 ₺	%1,1	70	39.040,65 ₺	139.540,65 ₺	1.993,44 ₺
19	101.000,00 ₺	%1,1	70	39.234,88 ₺	140.234,88 ₺	2.003,36 ₺
20	100.900,00 ₺	%1,1	70	39.196,03 ₺	140.096,03 ₺	2.001,37 ₺
21	100.875,00 ₺	%1,1	70	39.186,32 ₺	140.061,32 ₺	2.000,88 ₺

Figure 17. Manipulations on principal and periods for target monthly payment by Nurdan

In the second part of Task 4, an interview is held with the students on the case of a loan. In these interviews, the students are asked to prepare a worksheet where they could manipulate the variables in order to make a proposal suitable for the client's (researcher plays this role) wishes and present these proposals to him.

In the case designed as a vehicle loan, it is observed that Doğuş, Nurdan and Sema are able to perform manipulations intended for the monthly payment. Half of the students (Didem, Nurdan, Sema and Doğuş), are successful in the formulas in which =if is used on the interest policy. Didem's calculations based on this case are shown in Figure 18.

The Case study: Mr. Aslan, who wants to take a vehicle loan of 40000 TL, comes to the bank for an interview. Help the customer to make a decision by calculating the credit expectations of the customer, taking into account the interest policies.

Didem: Mr. Aslan, as you see, when we increase the number of periods, both the interest rate and your monthly payments increase.

Mr. Aslan: :I think the amount of interest is increasing, not the monthly payments.

Didem: Yes, I'm sorry. However, you will pay more total money out of this way.

Mr. Aslan: But the monthly payment is the most important thing for us because I need to control my budget. My payment should not exceed 2000 TL.

Didem: Then 26 months is suitable for you. But again, I recommend you to consider 23 months because the interest rate increase after 24. months. There is an excess of around 122 TL, does it force you?

Mr. Aslan: I think it would be more appropriate as well, thank you..

F11

Figure 18. Manipulations according to costumer's wishes by Didem

Considering the interview, Didem constantly warns the customer about the interest rate although the priority of the customer is the monthly payment amount. Didem efforts to do appropriate payment plans, instead of keeping the monthly payment amount constant. Although one of the reasons is the changing after 24. months, it is seen that Didem could not formulate a constant monthly payment, 2000 TL. The researcher in the role of Mr. Aslan reminds the monthly payment does not increase. Despite that, Didem enquires whether increasing the monthly payments is affordable or not when the number of periods is shortened. In this way,

she tries to take the customer's priority towards her known calculations. Accordingly, although Didem could not keep the monthly payment constant, she could manipulate and interpret different variables such as monthly payment, interest amount and interest rate.

An overview of the process of building an instrument from spreadsheets

The processes revealed by the students for the four outcomes are analyzed throughout the research. These processes observed in the dimensions of instrumentalization and instrumentation are indicated in Table 6.

Examining Table 6, it is seen that the students do not have difficulties in the processes of instrumentalization. In general, students can create appropriate formulas for simple and compound interest calculations. However, it is seen that there are mistakes in writing =if in Task 4. It is observed that some students prefer to enter the interest rate manually instead of cell addresses. Nevertheless, dragging is accepted by the students for manipulations, it is seen that there are students to turn to use features that they feel more comfortable with, such as editing the cell address for each row, copy-pasting instead of fixing.

Table 6. Students' schemes identified on the process

	Outcomes	Akın	Ceylin	Didem	Doğuş	Hatice	Nurdan	Sema	Şengül
Instrumentalization	1. Formulating	1	√	√	√	x	√	√	√
		2	√	√	√	√	√	√	√
		3	√	√	√	√	√	√	√
		4	x	x	x	√	x	x	√
	2. Entering cell addresses	1	√	√	x	x	√	√	√
		2	x	√	x	x	√	√	√
		3	√	√	√	√	√	√	√
		4	√	√	√	√	√	√	√
	3. Formatting cells	1	√	x	√	√	√	√	√
		2	√	√	√	√	√	√	√
		3	√	√	√	x	√	√	√
		4	√	√	√	√	√	√	√
	4. Fixing	1	N	N	N	N	N	N	N
		2	√	x	√	√	√	√	x
		3	√	x	√	√	√	√	x
		4	√	x	√	√	√	√	x
	5. Dragging	1	N	N	N	N	N	N	N
		2	√	√	√	√	√	√	√
		3	√	√	√	√	√	√	√
		4	√	√	√	√	√	√	√
Instrumentation	1. Constructing algebraic structures	1	√	√	√	√	√	√	√
		2	√	√	√	√	√	√	√
		3	√	√	√	√	√	√	√
		4	√	√	√	√	√	√	√
	2. Explaining why	1	√	√	√	√	√	√	√
		2	√	√	√	√	√	√	√
		3	x	√	√	x	√	√	√
		4	x	√	√	x	√	√	√
	3. Explaining the rule or relationship	1	√	√	√	√	√	√	√
		2	x	x	x	x	x	x	x
		3	x	x	x	x	x	x	x
		4	x	√	√	√	√	√	√
		1	√	√	√	√	√	√	√
		2	√	√	√	√	√	√	√

4.Generalizing the process to many examples	3	√	√	√	√	√	√	√	√
	4	√	√	√	√	√	√	√	√
5.Finding the unknown	1	√	√	√	√	√	√	√	√
	2	√	√	√	√	x	√	√	√
	3	x	x	√	√	x	√	√	√
	4	x	x	√	x	x	√	√	√

√: Performing, x: Not performing, N: The task does not include the process

It is seen that students can construct the algebraic structure and explain their calculations based on the spreadsheets for simple and compound interest. Although they make sense to trace of constructing compound interest onto consecutive simple interest calculations in spreadsheets, they could neither establish meaningful relationships between them nor understand the changing the mathematical structures. Another prominent point in the Tasks is that students who can create formulas using the cell addresses during the formulation phase are also successful in generalizations. When students examine the effect of the variables on the calculations, few students could formula for each variable. Instead, they try multi manipulations including one more than variables for intended results.

Instrumentalization	Ceylin:	Honestly, spreadsheets are useful more than calculators, especially in multi-manipulations ..in what way? You can see them all together, it is not happening on the calculator. ...I had a hard time creating the penny (Kr). Writing the percentage made my job easier. I am getting tired of typing parentheses in the calculator.
	Şengül:	...it is easy to use spreadsheets to do more calculations.
	Nurdan:	...visuality is well. I could see all the calculations.
	Akın:	...we did a lot of calculations from simple to compound (interest). If we do this with a calculator, it would take half an hour. And we definitely make mistakes so many in the calculations.
	Sema:	Creating a currency from financial and entering a percentage (formatting cells) made the calculations readable. We could see where the money is and what the rate is. When we write in the notebook, it is confusing because I take irregular notes.
	Didem:	I entered the percentage incorrectly, but I didn't realize it until the total amount was high. If we hadn't turned the money from the financial (formatting cells), I still wouldn't know. In order to understand the calculations, we must have habits in spreadsheets, we need to know how the rules (formulas) are written. Now I feel like I have memorized the rules (formulas) a little bit.
Instrumente	Hatice:	I thought that all calculations (banking transactions) were done with simple interest.

- Doğuş: While reaching the compound from simple interest, I thought that the result would not be the same. I was surprised when it came out equal. If I didn't see this, I would say they were unrelated things.
 ...I found that (abnormal) amount but I wouldn't have understood it if you hadn't told me.
 ...I think that the expectation of the customer is more important than other variables. The interest rate seems to be effective, but the rate cannot be changed at will. I understand that customers pay more attention to the principal and the monthly payment.
- Sema: These calculations helped me to understand the range of the real interest rates.
 ...In my worksheet, the effect of the rate was greater. In my opinion, the rates are asked firstly when taking out a loan which is the reason.
- Ceylin: I did the dragging correctly. I have created the formulas correctly. But I don't know if the results are right or wrong.
 I can decide more easily when I see all the calculations because I have done them together. Thus I can balance the interest rate and the number of periods more easily.
- Nurdan: I couldn't make a full comparison of which variable is more effective. But when I tried the 1% to 10% rate, it seemed to me that the interest rate was more effective. I thought that all calculations (banking transactions) were done with simple interest.

Examining the students' explanations on the use of spreadsheets, The use of cell addresses in formulas and the ability to perform many calculations without blocking other calculations are expressed as an important convenience that increases visibility and editing. Similarly, it is stated that the dynamism in the worksheets by creating appropriate formulas based on the cell address reduces mistakes. The students stated that the worksheets created on the spreadsheets offer a readable structure if they are arranged in an accordance format.

Regarding the handling of the concept of interest in spreadsheets; the students express that they have gained awareness within the concepts of simple and compound interest. The students state that the relationship between simple and compound interest can be seen thanks to sequential calculations in spreadsheets. In addition, it is stated that abnormal numbers in the calculations can be noticed with spreadsheets features such as formatting cells, besides the current values becoming meaningful with the created formulas. Moreover, it is stated that multiple manipulations are an important factor in examining the effects of the variables handled in interest calculations so that students can process the calculations in the intended direction.

Conclusions and Suggestions

In the study, the instrumental processes in Spreadsheets for students are examined through tasks prepared for the concept of interest which is one of the topics that students have difficulty with. Instead of formula-based learning using paper-pencil, the study is designed on the tasks for a conceptual development regarding the changes in variables on spreadsheets

regarding the students' mathematics levels. Performing tasks on spreadsheets allows multiple manipulations and tracing of them. Considering the expressing the students who have done the same calculations on paper-pencil and calculator before; it can be stated that spreadsheets offer possibilities regarding the multiple calculations, it allows to see numerous calculations at the same time as well as it has more readable worksheets by formatting cells (Sugden & Miller, 2011).

In order to carry out the manipulations, the necessity of cell addresses is adopted by the students so that entering cell addresses is preferred consciously instead of manual entries. In this way, it is stated that the calculations performed by paper-pencil and calculators are dynamized in spreadsheets. However, it is observed that some mistakes using schemes in spreadsheets such as not using/misusing fixing and dragging. This issue causes some students to use the time ineffective as well as to be unable to monitor variable changes.

It is seen that students who lay themselves paths by their reasoning skills during the instrumental transformation in spreadsheets enrich their instrumentalization processes. Accordingly, instrumentalization refers to a process based on conceptual structure rather than just the use of the tool (Drier, 2001). Besides, checking the results in the monitoring of the variable changes let the students get an idea about the adjustment of the created formulas. This shows that the instrumentalization processes emerging in the study are fed by the instrumentation processes (Özdemir Erdoğan, 2016).

The results obtained indicate that the instrumentalization processes are necessary but not sufficient for the instrumentation processes. It is seen that the correct formulas and calculations in spreadsheets are not reflected in the conceptual developments of all students. The fact that a couple of students who use handle correct calculations and formulas cannot interpret the relationships between variables correctly and notice abnormal values can be expressed for this.

It is seen that the students have no difficulty in constructing the algebraic structure of simple and compound interest formulas in spreadsheets. Considering the examinations on simple and compound interest variables, it is seen that some students have difficulties in using the interest rate, similar to the literature (Chong et al., 2015). For example, when writing 0.0189 as a decimal instead of 1.89%, there are mistakes in both the number of digits and the place of use of the dot. However, it is observed that some students develop the ways using spreadsheets features such as formatting cells for the correct interest rate to provide convenience in calculations.

Students in general generally make sense of the compound interest as a result of sequential simple interest calculations. In contrast to the study of Marley-Payne & Dituri, (2019) the students can compare compound and simple interest results. it is thought that spreadsheets leads the conceptual development of the students in this direction by indicating

sequential calculations together (NCTM, 2015). The reflection of the fact that compound interest is a consequence of sequential simple interest has similarities with the literature (Abramovich, 2018; Haspekian, 2014; Park et al., 2013). In examining the effects of the variables on the results, it can be said that the students can interpret linear relationships, for example, the reflection of the increase in the principal on the interest amount and the total amount. Nevertheless, they have difficulties with non-linear exponential changes, for example, the increase in the number of periods reduces the monthly payment amounts. Moreover, the spreadsheet environment has the potential with multi-manipulations to turn into an effective tool by the students in examining and comparing the effects of the variables. Students can monitor the change of values, direct the manipulations and interpret the results by estimating through multiple manipulations and by making numerous practices in calculations (Hubbard, et al., 2016; Pournara, 2013).

The expectation from people who work in the banking and insurance market is that they can manipulate the variables used in the calculations according to customers' expectations. Regarding this, it is thought that the tasks contribute students to developing their reasoning skills. The use of current values in calculations leads to raising students' awareness of the concept of interest on calculations and interpretations of the concept. In addition, in terms of mathematics education, the use of spreadsheets as a useful learning tool to determine and examine variables in other mathematical concepts is considered important for students' conceptual development and increasing their skills in using technology.

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Öğrencilerin Faiz Kavramı ve Hesaplarında Elektronik Tablo Kullanımlarına Enstrümantal Oluşum Açısından Bir Bakış

Özet:

Elektronik tablolar verilerin düzenlenmesi, sunulması ve gerekli hesaplamaların yapılmasında, veri gruplarında değişkenler arasındaki ilişkinin incelenmesinde sunduğu dinamik potansiyel sayesinde matematik eğitimi alanında da kullanılan ofis programlarıdır. Araştırmalar öğrencilerin faiz çeşitleri arasındaki bağlantı, faiz formüllerindeki değişkenlerin etkisinin belirlenmesinde zorluklar yaşadıklarını göstermektedir. Bu çalışmanın amacı da elektronik tablo ortamında öğrencilerin matematiksel yapısını anlamakta zorlandıkları faiz kavramının ele alındığı etkinliklerde öğrencilerin elektronik tablo kullanımlarını enstrümantal oluşum açısından incelemektir. Enstrümantal oluşum, öğrencilerin araç kullanımları ile kavramsal öğrenmeleri arasındaki etkileşimi ortaya koyan, teknolojik ortamlarda gerçekleştirilen karmaşık öğrenme süreçlerinin analizini sağlayan teorik bir yaklaşımdır. Araştırma bir devlet üniversitesinde finans matematiği dersini alan sekiz öğrenciyle gerçekleştirilmiştir. Ekran kayıtları, klinik görüşmeler ve gözlem notlarıyla elde edilen verilerin tematik analizi yapılmıştır. Araştırma sonuçları öğrencilerin elektronik tablonun ardışık işlemleri sunma potansiyeliyle basit ve bileşik faiz arasındaki ilişkiyi görebildikleri, çoklu manipülasyonlar yoluyla tahmin yöntemi üzerinden değerlerin değişimlerini yorumlayabildikleri, bu manipülasyonların gerçekleştirilebilmesinde hücre adreslerine dayalı veri girişinin gerekliliğini benimsediklerini göstermektedir.

Anahtar kelimeler: faiz, enstrümantal oluşum, elektronik tablo, enstrümantasyon, enstrümantalizasyon

Geniş Özet

Giriş

Teknoloji kullanımının öğrenmeye pozitif etkisinin oluşturulabilmesi için öğrenme ortamının uygun tasarımı ve araç ile matematiksel kavramların ilişkisinin doğru kurgulanması gerekmektedir (NCTM 2015; Van De Walle vd., 2015). Elektronik tablo (ET) verilerin tablolar halinde düzenlenmesi, kullanılması ve sunulması için tasarlanmış, öğretim ortamlarında sıkça yararlanılan bir yazılımdır. ET, hücre adresleri, hücre biçimlendirme ve formül oluşturma gibi özellikleri ile sayısal veriler arasında cebirsel ilişkilerin izlenmesinde katkısı ile muhakeme yeteneği ve uygulama becerisi kazandıran etkili bir öğrenme materyalidir (Drier, 2001; Haspekian, 2014; NCTM, 2015; Park vd., 2013). Yığılmalı bir bilim dalı olan matematikte kavramsal geçişlerin sağlanmasında, çoklu verilerin hesaplanmasında kolaylık sağladığı, dinamik veri gruplarında değişkenler arasındaki ilişkiyi ortaya çıkardığı belirtilmektedir (Abramovich, 2018; Mays, 2015).

Yüzde ve faiz hesaplamaları matematik öğretiminin çeşitli kademelerinde, öğretim programlarında yer verilen kavramlardan biridir (Paurana, 2013; Sugden vd., 2015). Literatürde öğrencilerin faiz kavramı ve hesaplamaları ile ilgili bazı zorluklar ile karşılaştıkları görülmektedir. Yüzde, oran ve faiz çeşitlerinin birlikte ele alındığı çalışmalarda; faiz

hesaplarının karıştırılması ve anlamlı işlemler gerçekleştirilememesi (Sugden & Miller, 2011), yapılan faiz hesaplamalarının değişkenlere bağlı açıklanamaması (Bakker vd., 2006; Hoyles vd., 2010; Hubbard vd., 2016) faiz çeşitleri arasındaki ilişkinin kurulamaması ve yorumlanamaması (Pournara, 2013), basit ve bileşik faiz işlemlerinin zaman senkronizasyonunun yapılmaması (Feng & Kwan, 2015), faiz oranlarının hesaplamalarda hatalı kullanılması (Chong vd., 2015), güncel faiz parametrelerinin takip edilmemesinden kaynaklı anormal değerlerin fark edilememesi (Marley-Payne & Dituri, 2019; Sugden & Miller, 2011) bu zorlukların başlıcaları olarak ifade edilebilir.

Teorik Çerçeve: Enstrümantal Oluşum

Araştırmada ET'den yararlanılan öğretim sürecinin incelenmesi açısından enstrümantal oluşum teorisi temel alınmıştır. *Enstrümantal oluşum*, araç ile öğrenme süreci arasındaki ilişkiyi, öğrenenlerin araç kullanımında geliştirdikleri teknikleri ve kavramsal gelişimlerini inceler (Trouche, 2004). Enstrümantal oluşum *enstrümantalizasyon* ve *enstrümantasyon* olmak üzere iki boyut üzerinden ele alınır. *Enstrümantalizasyon*, kullanıcıların aracı kişiselleştirerek çözüme götüren zihinsel yollar belirlemeleri iken, *enstrümantasyon*, bu yolların matematiksel altyapılarını ve bunun enstrüman oluşumu ile ilişkisinin ele alınmasıdır (Trouche, 2018). *Enstrümantasyon* öğrenenlerin görev-arac ilişkisi üzerinden geliştirdikleri, matematiksel bir gelişimin ötesinde enstrümantalizasyon ile birlikte değerlendirilmesi gereken hibrid bir süreçtir (Trouche, 2018).

Bankacılık ve finans bölümü öğrencilerine işe başlama yıllarında istihdam edildikleri şirketler tarafından çalışma süreçlerini modelleyen hizmet içi eğitimler verilmektedir. Bunun en önemli sebebi olarak öğrencilerin alan üzerinde yeterliklerinin geliştirilmesi gerekliliği dile getirilmektedir (Güvenç & Yücebalkan, 2017). Yüzde ve faiz hesaplamaları bölüm öğrencilerinin sık kullandıkları kavramlardandır. Bankacılık sektörünün ürün yelpazesinde sunulan faiz türevleri, vade oranları, kredi hesaplamaları gibi birçok işlem bu kavramlarla ilişkilidir. Sektör çalışanlarında ilgili hesaplamalarını doğru yapmalarının yanında, bu hesaplamaları müşteri isteğine göre tasarlamak ve zaman, oran, sermaye gibi farklı değişkenlerin manipülasyonunda ortaya çıkabilecek değişimleri önceden sezmek, yorumlamak, bu durumu uygun şekilde izah etmek, kurum-müşteri beklentilerini optimum seviyede karşılamak gibi becerilere ağırlık verilmektedir.

Çalışmanın amacı

Bu çalışmanın amacı faiz işlemlerini ele almak için tasarlanan bir öğrenme ortamında öğrencilerin ET kullanımlarının enstrümantal oluşum açısından incelenmesidir. Bu kapsamda aşağıdaki araştırma sorularına cevap aranmaktadır:

1. Öğrencilerin faiz işlemlerinde ET fonksiyon ve özelliklerini kullanımları nasıldır?
2. ET kullanımının öğrencilerin faiz kavramı gelişimine katkısı nedir?

Yöntem

Bu çalışmada nitel araştırma yaklaşımlarından biri olan durum çalışması yöntemi benimsenmiştir. Durum çalışması, bir durumu, dersi veya bir etkinliği ayrıntılı olarak inceleyerek neden ve nasıl sorularına cevap veren bir yöntemdir (Yıldırım & Şimşek, 2008). Durum çalışması, sonuçlardan ziyade süreçle, gerçekleri doğrulamak yerine vakanın bağlamıyla ve keşfetmekle ilgilenir (Merriam & Grenier, 2019). Öğrencilerin ET'yi bir araçtan enstrümana dönüştürme süreçlerinin incelenmesi amaçlandığından çalışmada durum çalışması yöntemi kullanılmıştır.

Katılımcılar: Araştırma, Batı Akdeniz'de bulunan bir devlet üniversitesinde önlisans düzeyinde Bankacılık ve Finans bölümünde 1. Sınıf finans matematiği dersini alan 89 öğrenci arasından 8 kişilik bir çalışma grubu ile gerçekleştirilmiştir. Araştırmada bilişsel düzey ve cinsiyet dağılımı dikkate alınarak çevreyi yansıtmak için uygun örnekleme yöntemi kullanılmıştır (Lehner, 1992). Çalışmaya katılım gönüllülük esasına dayalı olarak yapılmıştır. Öğrenciler mesleki dersleri kapsamında bir ofis programı olarak elektronik tabloyu tanımakla birlikte finans matematiği dersi kapsamında ilk kez kullanmışlardır.

Veri toplama araçları: Araştırmada ET ortamında dört etkinlik yapılmış, gerçekleştirilen etkinliklerin ürünleri ile öğrencilerin süreç içerisindeki becerileri ve düşüncelerini ortaya koyacak dokümanlar elde edilmeye çalışılmıştır (Merriam & Grenier, 2019). Araştırmanın veri toplama araçları; (1) öğrencilerin etkinliklerine dair ekran kayıtları, (2) klinik görüşmelerin ses kayıtları ve (3) araştırmacının tuttuğu gözlem notlarıdır. Birden fazla veri toplama aracı kullanarak araştırmanın verilerine dair geçerlilik güvenilirliğinin artırılması hedeflenmiştir (Yıldırım & Şimşek, 2008).

Araştırma Süreci: Etkinlikler elektronik tablo ortamında finans matematiği dersi kapsamında kurum tarafından belirlenmiş ders içeriklerinde yer alan kazanımlar ile birlikte literatürde ifade edilmiş becerileri de dikkate alarak hazırlanmıştır (Hoyles, 2018; Paunara, 2013). Buna göre

etkinlikler dört temel kazanım üzerine inşa edilmiş ve her bir kazanım için öğrencilere bir yönerge sunulmuştur.

Kazanımlar : (K1). Basit faiz ve bileşik faiz hesaplamalarını kâğıt kalemle, hesap makinasında ve ET üzerinde yapabilir, (K2). Basit faizden bileşik faize geçişleri sağlayabilir, (K3). Bileşik faiz değişkenlerini yorumlayabilir, (K4). ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izleyebilir.

Öğrenciler aynı donanımlara sahip bilgisayarlar üzerinde Excel 2013 kullanarak bu etkinlikleri gerçekleştirmiştir. Beş haftalık uygulama süreci her hafta 45'er dakikadan iki seans şeklinde düzenlenmiştir.

Verilerin analizi: Çalışmada ekran kayıtları, klinik görüşmeler ve gözlem notlarından elde edilen veriler için tematik analiz yapılmıştır. Araştırmanın tematik analizi, enstrümantal oluşum yaklaşımının boyutları olan enstrümantalizasyon ve enstrümantasyona göre iki bölümde ele alınmıştır. Temalar elektronik tabloların işlevleri ve özellikleri açısından, Ainley vd. (2005) çalışmasından alınmıştır (Ainley vd., 2005). Bu analiz temaları, katılımcıların enstrümantal oluşum yaklaşımı çerçevesinde tanımlanan şemalarını ortaya koymaktadır. Elde edilen temalara göre analizler araştırmacılar tarafından birlikte yapılmıştır. Gerekğinde ses kayıtları ve ekran görüntüleri yeniden incelenmiş, araştırmacılar tarafından alınan notlarla karşılaştırılarak verilerin birbirini destekleyip desteklemediği kontrol edilmiş ve veri kaybı minimumda tutulmaya çalışılmıştır.

Enstrümantalizasyon Süreçleri

1. Formül oluşturma: -Hücre adreslerini kullanarak formül oluşturur, fonksiyon girişlerini doğru hücrelerden gerçekleştirir.
2. Hücre adresi kullanımı: -Hücrelerin ve hesaplamaların dinamikliğini sağlar.
3. Hücre biçimlendirme: -Para birimi vb. düzenlemelerle okunabilir bir sayfa hazırlar.
4. Sabitleme: -Sürüklemeler için gerekli yerlerde sabit (\$) kullanır.
5. Sürükleme: -Verilen sayıların örüntüsüne uygun, formüllere dayalı sürükleme özelliğini kullanır, manuel girişleri kullanmaz, çoklu manipülasyonda sürüklemeyi kullanır. Bu özelliğin amacının minimum manuel giriş ile maximum işlem hacmini amaçladığını fark eder.

Enstrümantasyon Süreçleri

1. Cebirsel yapıyı inşa edebilme: -Formül oluşturarak basit ve bileşik faiz işlemlerini gerçekleştirir.
2. Nasıl yaptığını açıklayabilme: -Oluşturulan formülleri ve ET özelliklerini matematiksel altyapıya uygun şekilde açıklar.
3. Kuralı ya da ilişkiyi açıklayabilme: -Faiz işlemleri ve sonuçları arasındaki ilişkiyi açıklayabilir, faiz değişkenlerinin sonuçlara etkisini açıklayabilir, faiz değişkenlerine göre sonuçları tahmin edebilir, faiz değişkenlerini istenen sonuçlara göre manipüle edebilir.
4. Yapılan işlemi farklı örneklere genelleme: -ET üzerinde kurduğu sistem üzerinden manipülasyonlar gerçekleştirebilir.
5. Bilinmeyi bulabilme: -Basit ve bileşik faiz değişkenlerine dair sonuçlara ulaşabilir.

Bulgular

Öğrencilerin araştırmaya konu edilen dört kazanım için ortaya koyduğu beceriler araştırma boyunca analiz edilmiştir. Bulgularda, öğrencilerin enstrümantalizasyon süreçlerinde zorlanmadıkları görülmektedir. Öğrenciler genel olarak basit ve bileşik faiz işlemleri için uygun formülleri oluşturabilmiştir. Ancak Etkinlik 4'te *Eğer (if)* kodunu yazmada hatalar oluştuğu görülmektedir. Hücre adresine dayalı giriş yapmak yerine bazı öğrencilerin faiz oranını manuel girmeyi tercih ettikleri gözlenmiştir. Sürüklemeye, manipülasyonlar için öğrencilerden kabul görürken, bazı öğrencilerin hücre sabitleme yerine her satır için hücre adresini düzenleme ya da kopyala-yapıştır gibi kendilerini daha rahat hissettikleri kullanımlara yöneldiği görülmektedir.

Öğrencilerin basit ve bileşik faiz için ET ortamına dayalı olarak cebirsel yapıyı inşa edebildikleri ve yaptıkları işlemi açıklayabildikleri görülmektedir. Bileşik faizin ardışık basit faizlerden oluşmasına dair ET üzerinde geliştirilen izleme anlamlı gelse de iki faiz formülü arasındaki matematiksel yapı değişikliğinin ve ilişkisinin açıklanamadığı görülmektedir. Etkinliklerde öne çıkan diğer bir nokta ise formülleştirme aşamasında hücre adresini kullanarak formül oluşturabilen öğrencilerin genellemelerde de başarılı olduğu yönündedir. Faiz işlemlerinde değişkenlerin değerleri bulunurken o değişkene özgü bir formül oluşturabilme becerisi sınırlı kalmış, daha çok çoklu manipülasyonlar yoluyla deneyerek istenilen sonuca ulaşıldığı gözlenmiştir.

Öğrencilerin faiz işlemleri için ET kullanımına yönelik açıklamaları incelendiğinde; formüllerde hücre adresi kullanımı ve çok sayıda hesaplamanın diğer hesaplamaları engellemeden yapılabilmesi, görülebilirliği ve düzenlenebilirliği artıran önemli bir kolaylık

olarak ifade edilmektedir. Buna paralel olarak ET üzerinde hücre adresine dayalı uygun formül oluşturularak hazırlanacak sayfalarda oluşan dinamikliğin hata riskini azalttığı dile getirilmiştir. Öğrenciler açıklamalarında, ET üzerinde oluşturulan çalışma sayfalarının konunun formatına uygun düzenlemesi halinde okunabilir bir yapı sunduğunu ifade etmişlerdir.

Faiz konusunun ET’de ele alınmasına yönelik yapılan değerlendirmelerde ise; öğrenciler basit ve bileşik faiz kavramları çerçevesinde farkındalık kazandıklarını dile getirmektedir. Öğrenciler basit ve bileşik faiz işlemleri arasındaki ilişkinin ET’de yürütülen ardışık işlemler sayesinde görülebildiğini ifade etmişlerdir. Bununla birlikte hesaplamalarda ortaya çıkan anormal değerlerin hücre biçimlendirme gibi ET özellikleri ile fark edilebildiği, güncel değerlerin oluşturulan formüllerle anlamlı hale geldiği dile getirilmiştir. Diğer taraftan faiz işlemlerinde ele alınan değişkenlerin etkilerinin incelenmesinde çoklu manipülasyonun önemli bir faktör olduğu, bu sayede istenilen yönde hesaplamaların yapılabilirliği çalışmanın öğrencilere kazandırdığı bir beceri olarak ifade edilmiştir.

Sonuç ve Tartışma

Bu çalışmada öğrencilerin zorlandıkları konulardan biri olan faiz işlemleri ile ilgili olarak hazırlanan etkinlikler aracılığıyla ET’nin öğrenciler için enstrümantal dönüşümü incelenmiştir. Hazırlanan etkinlikler formüle dayalı bir öğrenme yerine, öğrencilerin matematik düzeyleri de dikkate alınarak, değişken değişimlerinin ET üzerinde izlenmesine dayanan bir kavramsal gelişime zemin hazırlamıştır. Etkinliklerin ET üzerinde gerçekleştirilmesi öğrencilerin çoklu manipülasyonlarına imkan vermektedir. Araştırmada ET’nin çoklu hesaplamalar yapma açısından sunduğu imkanların dile getirildiği; ET’nin yapılan işlemleri aynı anda görülebilir kıldığı ve hücre biçimlendirme ve çalışma sayfası formatı yoluyla okunabilir bir yapı sunduğuna vurgu yapıldığı görülmektedir. Bu manipülasyonların gerçekleştirilebilmesinde hücre adreslerine dayalı veri girişinin gerekliliği öğrenciler tarafından benimsenmiş, sayısal veri girişleri yerine hücre adresine dayalı veri girişleri bilinçli şekilde tercih edilmiştir. Bu sayede gerçekleştirilen işlemlerin ET ortamında dinamikleştirildiği ifade edilmiştir. Bununla birlikte öğrencilerin ET kullanım şemalarındaki farklılıkların çoklu manipülasyonların sürdürülmesinde sorunlar oluşturduğu görülmüştür. Bu durumun bazı öğrencilerin, zaman ve işlem tasarrufu yapamamalarına, değişken değişimleri izleyememelerine neden olduğu gözlenmiştir. ET’nin enstrümantal dönüşüm sırasında muhakeme becerilerini kullanan öğrencilerin ise ortaya koyduğu alternatif çözüm yolları ile enstrümantalizasyon süreçlerini zenginleştirdiği görülmektedir. Buna göre enstrümantalizasyon salt aracın kullanımından ziyade kavramsal temellere dayalı bir süreci ifade etmektedir (Drier, 2001). Buna benzer şekilde,

değişken değişimlerinin izlenmesinde değişkenlerin sonuçlarının kontrol edilmesi, oluşturulan formüllerin doğruluğu hakkında da öğrencilere fikir vermiştir. Bu durum çalışmada ortaya çıkan enstrümantalizasyon süreçlerinin enstrümantasyon süreçlerinden beslendiğini göstermektedir (Özdemir Erdoğan, 2016).

Enstrümantasyon süreci için de enstrümantalizasyon sürecinin gerçekleşmesinin gerekli ama yeterli olmadığını gösteren sonuçlara da ulaşılmıştır. ET’de doğru formül ve işlemlerin tüm öğrencilerin kavramsal gelişimine yansımadağı görülmektedir. Doğru işlem ve formül kullanan bazı öğrencilerin değişkenler arasındaki ilişkileri doğru yorumlayamaması ve anormal değerleri fark edememeleri buna dayanak olarak ifade edilebilir.

Araştırmada öğrencilerin ET üzerinde basit ve bileşik faiz formüllerinin cebirsel yapısını inşa etmede zorlanmadıkları görülmektedir. Basit ve bileşik faiz değişkenlerine yönelik incelemeler dikkate alındığında ise bazı öğrencilerin literatüre benzer şekilde faiz oranını kullanmakta zorlandıkları görülmektedir (Chong vd., 2015). Bununla birlikte bazı öğrencilerin faiz oranının doğru kullanımı için hücre biçimlendirme gibi ET özelliklerini kullanarak geliştirdikleri yolların hesaplamalarda kolaylık sağladığı görülmüştür.

Öğrenciler genel olarak ardışık basit faiz işlemlerinin bir sonucu olarak bileşik faiz sonuçlarını değerlendirebilmektedir. Yine bileşik faiz sonuçları ile basit faiz sonuçları Marley-Payne & Dituri, (2019) çalışmasının aksine karşılaştırılabilmektedir. ET ardışık işlemleri birlikte gösterebilme özelliği ile öğrencilerin bu yöndeki kavramsal gelişimlerinde rol oynamıştır (NCTM, 2015). ET üzerinde sunulan bileşik faizin ardışık basit faiz işlemlerinden oluşmasına yönelik sürecin kavramlar arası geçişlere yol açması bu yöndeki literatür ile benzerlikler taşımaktadır (Abramovich, 2018; Haspekian, 2014; Park vd., 2013). Değişkenlerin sonuçlara etkisinin incelenmesinde öğrencilerin doğrusal ilişkileri yorumlamakta, örneğin anapara artışının faiz miktarı ve toplam tutara yansımadağı, zorlanmadıkları ancak doğrusal olmayan üstel değişimleri, örneğin dönem sayısının artmasının aylık ödeme tutarlarını azaltması, yorumlamakta zorlandıkları ve anlamlandıramadıkları gözlenmektedir. Bununla birlikte değişkenlerin etkisinin incelenmesinde ve karşılaştırılmasında öğrenciler tarafından ET’nin çoklu manipülasyon potansiyeli etkin bir araca dönüştürülmüştür (Sugden & Miller, 2011). Öğrenciler çoklu manipülasyonlar yoluyla ve hesaplamalarda çok sayıda denemenin yapılmasıyla tahmin yöntemi üzerinden değerlerin değişimini izleyebilmekte, manipülasyonları yönlendirebilmekte ve sonuçları yorumlayabilmektedir (Hubbard vd., 2016; Pournara, 2013).

Bankacılık ve sigortacılık sektöründe çalışanlardan beklenti, hesaplamada kullanılan değişkenlerin müşteri beklentilerine göre manipüle edilebilmesidir. Bu itibarla etkinliklerde yer verilen görevlerin öğrencilerin bu yöndeki gelişimlerine katkı sunduğu düşünülmektedir. Yapılan işlemlerde güncel değerlerin kullanılması faiz kavramı, hesaplamaları ve yorumlamalarına dönük öğrencilere bilinç kazandırırken kurumsal beklentileri de karşılamaya dönük önemli bir adım olarak görülmektedir.