Examining graphic drawing skills for a socioscientific problem situation: The SIR model Covid-19 example

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The aim of the study is to examine the graphing skills of prospective elementary mathematics teachers for a socioscientific problem situation related to Covid-19. The research is a qualitative research and was carried out with the case study method.The participants consisted of 43 prospective elementary mathematics teachers studying in the third year of a state university in Turkey. Typical case sampling, one of the purposive sampling methods, was used to determine the participants. In the research, an open-ended question that requires drawing three graphs with vital aspects based on a socio-scientific situation-based scenario was used as a data collection tool. Data analysis consists of two stages. First, the graphs drawn by the prospective elementary mathematics teachers were scored with the descriptive analysis method.Then, the errors in the graphics drawn using the content analysis method were grouped and determined. When the data were analyzed, it was observed that a significant portion of prospective elementary mathematics teachers had deficiencies in their ability to draw graphs about the problem situation in the context of Covid-19. For this reason, when teaching graphics, drawing activities that require more context-based qualitative understanding or technology-assisted teaching applications can be used.

Keywords: Coronavirus, covid-19, SIR model, socioscientific, graph drawing

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1 Introduction

Controversial, complex, open-ended and unanswered issues in which societies have different views are called socioscientific issues (Sadler, 2004). In other words, they are subjects that cannot be agreed upon by scientists or that have multidimensional consequences for the environment, health, technology and science (Sadler & Zeidler, 2009). Many events such as pollution rates, change in rainforests, global warming, nuclear energy, drug trials, vaccines, AIDS, EBOLA, SARS infection rates, unemployment numbers can be given as examples of socioscientific issues. In this respect, although socioscientific issues appear within the scope of science and social studies, mathematical skills are also needed to fully understand scientific issues that affect social life and are frequently discussed in daily life. In the related literature, this situation is defined as social mathematics (Rosander, 1937 cited. Öntaş, 2006). It is stated by Öntaş (2006) that many mathematical skills such as understanding representations such as maps, charts and graphs, data collection and measurement, ratio-proportionality, range, standard deviation percentage change (increase/decrease) are necessary for the teaching and learning of social mathematics. In particular, graphics are important visual representations that enable individuals to communicate cognitively by visualizing abstract thoughts and complex data in the problem-solving process (Özgün-Koca, 2008). In this respect, in mathematics, which is one of the courses that contain too many abstract concepts, graphics have a great place and importance, but they also have an interdisciplinary and supra-disciplinary function. Graphics representing the rate-time change and the increase in the number of bacteria in science are the most typical examples of these representations. In addition, graphs are frequently used in social sciences such as statistics and economics. In addition to these, graphics are used when analyzing the results of researches made to inform the public about social and economic issues in the press. Therefore, it has become a necessity for individuals to have sufficient knowledge of graphics so that they can interpret the graphics they encounter in daily life, reach the right results and continue their lives as a conscious society member.

When the studies on graphics are examined, it is seen that individuals at almost every education level have learning difficulties and misconceptions about graphics. In particular, most of the studies on identifying misconceptions in various dimensions of graphic literacy skills are aimed at elementary school (Bursal & Yetiş, 2020; Curcio, 1987; Güler, 2019; Hotmanoğlu, 2014; Kaynar & Halat, 2012; Özmen, Güven, & Kurak, 2020; Polat, 2016; Sezgin-Memnun, 2013; Şahin, 2019; Tortop, 2011; Tosun, 2021; Wu, 2004; Yılmaz & Ay, 2016), high school (Özaltun-Çelik, 2021; Özgen, Aygün & Hazanay, 2017; Tekin & Konyalıoğlu, 2009) and university students (Akar, 2018; Aydan, 2020; Aydın & Tarakçı, 2018; Bayazıt, 2011; Bragdon, Pandiscio & Speer, 2019; Dündar & Yaman, 2015). In the related literature, it has been seen that most of the studies conducted to examine the graphic skills of university students are for science and classroom prospective teachers. For this reason, Ersoy (2004) and Bayazıt (2011) state that many studies in the related literature use non-context-based formal questions related to physics concepts (path-time, height-slope, etc.) while examining graphic skills. In his study, Dugdale (1993) emphasized the importance of choosing examples from daily life in order to develop graphic skills beyond pointing out points in the graph or reading. When the studies were examined, it was observed that the students were more willing to express their opinions about the context-based graphics (Bayazıt, 2011; Roth & Bowen, 2001). According to Roth and Bowen (2001), it is not enough for a person to have the knowledge to use in creating a graphic in order to be able to read and interpret a graphic successfully. However, *"contextual dimension"* it is stated that, which is expressed as the *"the person must have intense interaction with the represented event and the demonstrative tool"* (Roth & Bowen, 2001). For this reason, it is thought that using context-based open-ended questions in this study will make it easier for prospective teachers to reflect their graphic drawing skills. According to the literature review, it was determined that most of the studies on socio-scientific status-based issues were focused on science education (Aydın & Karışan, 2021; Cian, 2020; Dawson & Carson, 2020; Karpudewan & Roth, 2018; Özcan & Gücüm, 2021; Yıldırım & Bakırcı, 2020). On the other hand, it has been determined that there are limited number of abroad (Maass, Doorman, Jonker & Wijers, 2019; Paige & Hardy 2014) and national studies (Kaleli-Yılmaz & Yurtyapan, 2021) on mathematics education on socioscientific issues. In the conducted study, the current coronavirus pandemic is seen as an important socio-scientific problem situation. As a matter of fact, many statistical figures, models and graphs are presented to the society every day about the coronavirus pandemic and interpreted in different ways. This situation makes understanding how the coronavirus pandemic process progresses a controversial issue for the society. In this respect, the coronavirus pandemic is an important socioscientific problem situation that requires the use of many mathematical skills such as graphics, statistics, algebra. One of the most common visual representations used to explain the coronavirus pandemic to the public is graphics. For this reason, it is thought that graphic skills are important in understanding the pandemic process by the society. In this study, the focus is on the graphic drawing skill, one of the graphic skills. The ability to draw graphs includes many skills such as axis labeling, axis selection, data entry (Gültekin, 2009; Mckenzie & Padilla, 1986; Temiz & Tan, 2009; Uyan & Önen, 2013). In addition, it is stated by Leinhardt, Zaslavsky, and Stein (1990) that drawing a graph is different from reading or interpreting graphs, since a new representation is created while drawing graphs. Skills in reading and interpreting graphics are used when creating this new representation. As a result, it is possible to say that the skill of drawing graphics has a more practical and comprehensive structure than reading and interpreting graphics. Therefore, with this study, it is thought that examining the graph drawing skills of elementary school mathematics prospective teachers for a socio-scientific problem situation related to Covid-19 will contribute to the relevant literature in terms of determining what mistakes they can make while drawing graphs. As a result, the aim of this research is to examine the graphing skills of elementary mathematics prospective teachers for a socio-scientific problem situation related to Covid-19. In the study carried out in line with this determined purpose, the main question "How are the graph drawing skills of elementary school mathematics prospective teachers for a socio-scientific problem situation related to Covid-19?" search for an answer to the question. In the research, within the framework of this main question, answers are sought for the following sub-problems about the elementary mathematics prospective teachers participating in the study:

- What is the level of graphing skills of elementary school mathematics prospective teachers regarding a socio-scientific problem situation related to Covid-19?
- What kind of mistakes do elementary mathematics prospective teachers make while drawing a graph about a socio-scientific problem situation related to Covid-19?

1.1 Theoretical framework

In this section, it is explained how the socio-scientific problem situation used to examine the graph drawing skills of elementary mathematics prospective teachers participating in the research was developed. In addition, the theoretical information on how to examine the graph drawing skills of elementary school mathematics prospective teachers in the research is presented in the context of the relevant literature.

In accordance with the purpose of the research, an open-ended question was developed in the study that requires drawing three interconnected graphs in the case of a socio-scientific situation-based problem related to life. While developing the problem situation in the open-ended question, it was inspired by the SIR [Susceptible - Infectious - Recovered] model, one of the mathematical models used to predict the spread of the epidemic in epidemiology. Based on the basic model developed by Kermack & McKendrick (1933), the model called SIR is closed to the outside, there are no birth and other death events caused by natural or other diseases, the incubation period of the infectious agent is instant, the age, geographical and social position of the individuals is homogeneous, the population is homogeneous. In a population where the disease is stable and the disease is transmitted only from person to person, the stages of an infectious disease are modeled with simple differential equations (Akpınar, 2012).

In this model, the population exposed to an infectious disease is divided into three groups. These are named as those who are likely to get the disease (Susceptible), those who are infected, that is, those who carry the disease (Infectious), and those who recover by gaining immunity against the disease (Recovered).

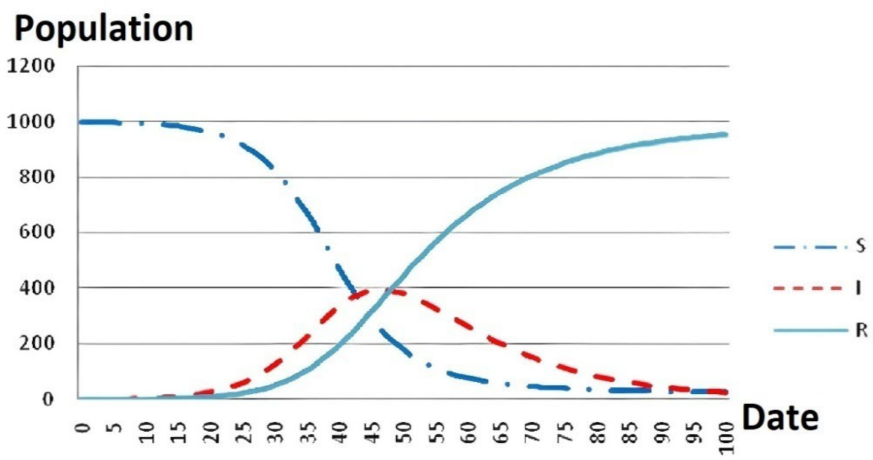


Figure 1. Example Course of an Infectious Disease in the SIR Model. (Akpınar, 2012).

In the SIR Model, the course of the epidemic is shown graphically within the framework of these three variables. The exemplary course of an infectious disease within the scope of the model is presented in Figure 1. The graphs drawn for the three variables in this model have a dynamic structure that affects each other in a procedural context. The fact that the graphics in the SIR model interact with each other and have a procedural structure requires the use of many skills together to solve the problem situation presented in the graphic drawing. It is thought that this situation will create a suitable problem situation in terms of determining the level of perception of prospective teachers' mistakes. Therefore, the SIR model was inspired by the development of an open-ended question aimed at identifying prospective teachers' graphing skills and the mistakes they made while drawing graphs.

In the related literature, it is seen that graphic literacy is generally handled in three dimensions as graphic reading, interpretation and drawing. Although it is stated by Lienhartd, Zaslavsky, and Stein (1990) that the skill of drawing graphics is quite different from reading and interpreting graphics because it is a new aspect of representation, it is an undeniable fact that these skills are interrelated. Actually, in many studies, it is stated that the difficulties students encounter in reading and interpreting graphics affect their graphics drawing skills (Aydın & Tarakçı, 2018; Tairab & Al Naqbi, 2004). In particular, in the study conducted by Tairab & Al Naqbi (2004), it was determined that the students' graph drawing skills were not good because they did not have sufficient knowledge and skills about graph interpretation. For this reason, it can be said that the ability to draw graphics has a structure that includes other skills. When the studies dealing with the misconceptions about graphics are examined, it is seen that the mistakes made in some studies are dealt with in a systematic way, and the students' level of perception of graphics is named as visual perception, quantitative perception and qualitative (global) perception (Bell & Janvier, 1981; Connery, 2007; Even, 1998; Kieran, 1992; Leinhardt, et al., 1990).

When the aforementioned studies are examined, it is seen that the most prevelant misconception is "perceiving graphics as a picture" and this is defined as "level of visual perception" (Bell & Janvier, 1981). According to Bell and Janvier (1981), people at the visual perception level perceive the graphic only as a picture. People at this level have no idea about the mathematical relations in the graph. On the other hand, students at the quantitative perception level have information about the relationship between the variables that add meaning to the graph. However, individuals at this level examine the graph point-by-point while interpreting the relationships between variables, or they need to perform algebraic operations (Leinhardt, et al., 1990). Therefore, students at the quantitative perception level cannot evaluate the holistic process of the graph because they are content to focus on the critical points (starting point, intersection point, height, etc.) given in the graph. At the qualitative (global) perception level, students can think about the holistic process of the graph, rather than dealing with the graph in point, algebraic and arithmetic terms, and can obtain a new graph based on a given graph (Bayazıt, 2011). Since they become a mathematical object together, they can manipulate and easily use these objects in any way they want (Sfard, 1992). Therefore, it can be said that the qualitative perception level has a structure that requires different skills compared to the other perception levels mentioned. In the light of the relevant literature, it is predicted that the mistakes to be detected in the graphic drawing in this study may be similar to the mistakes made in the above-mentioned perception levels. Therefore, it is considered appropriate to use the aforementioned perception levels in the interpretation of the mistakes that can be detected within the scope of the study.

Another sub-problem of the study, the rubric developed by Beler (2009) was inspired to determine the level of graphing skills of prospective elementary mathematics teachers for a socio-scientific problem situation related to Covid-19. Drawing graphs covers many skills such as axis labeling, axis selection, data entry (Gültekin, 2009; Mckenzie & Padilla, 1986; Temiz & Tan, 2009; Uyan & Önen, 2013). The mentioned skills and more are included in the rubric developed by Beler (2009). For this reason, it is considered to use the criteria in the rubric developed by Beler (2009) to determine the level of graphing skills for a socio-scientific problem situation related to Covid-19.

2 Method

The study was carried out using the case study method, one of the qualitative research methods. The case study method allows the researcher to observe the examined situation in its own flow and facilitates the identification and evaluation of the meanings in the minds of the participants about the situation (Denzin & Lincoln, 1998). This method also allows for an in-depth investigation of one or more situations (Çepni, 2018; Yıldırım & Şimşek, 2016). The main property that separates case studies from anothers is that it provides the opportunity to ask how and why questions about the subject under investigation (Yin, 1984). Furthermore, it also allows the use of different qualitative and quantitative data collection tools. In this wise, special cases can be investigated in detail within the framework of their nature. In this study, the socio-scientific problem situation related to Covid-19 used to investigate pre-service teachers' graphing skills is a special case. Therefore, the case study method was preferred in the research.

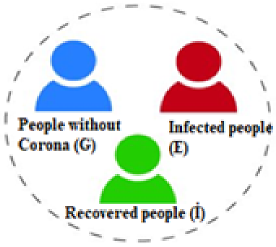
2.1 Participants

The participants were composed of 43 prospective teachers studying in the third year of elementary school mathematics teaching at a university in Turkey. Typical case sampling method, which is one of the purposive sampling methods, was preferred to form the study group. Typical case sampling is used to express situations that are not different from the population of the research in terms of basic characteristics (Marshall & Rossman, 2014). With this sampling method, individuals with average knowledge within the framework of the issue aimed to be researched are included in the research and an average view on the issue is obtained (Patton, 2005). In this study, since the ability to draw graphs on Covid-19 was investigated, it was determined as a criterion that pre-service teachers took general mathematics and mathematics teaching courses. It was thought that it would be better to conduct the study with third-year students, since they were thought to have completed these field-specific basic courses and had an average level of knowledge about graphics. In addition, during the determination of the prospective teachers participating in the research, sensitivity was shown to ensure that there was no illness or death in their relatives due to Covid-19. It was based on the voluntary participation of the researchers in the research. For the pre-service teachers participating in the research, these abbreviations were coded as T_1, T_2, ..., T_{42} and T_{43}.

2.2 Data collection tools

In the study conducted, open-ended questions were preferred in the examination of prospective teachers' graphic drawing skills for a socio-scientific problem situation. Open-ended questions are used to measure behaviors at the upper levels of the cognitive domain, especially at the synthesis and evaluation level (O'Neil & Brown, 1998). Therefore, open-ended questions were used since the graph drawing skills examined in this study are a synthesis-level behavior. According to Yee (2002), open-ended questions do not contain any fixed procedures that guarantee a correct solution. In addition, they are important question types in mathematics teaching in terms of reflecting many different solutions, perspectives, comments and results (Yıldız & Uyanık, 2004; Karaman & Şahin, 2014). The open-ended question posed in this study has only one correct drawing. However, in order to understand how students approach the graph (visual, quantitative or qualitative ways of thinking) when drawing correctly or incorrectly, the question "*After making your drawing, explain in detail how you drew the graph with verbal expressions.*" statement is included. Thus, it is aimed to examine in detail the approaches of prospective teachers in their drawings. In this respect, it is thought that the question used in the examination of prospective teachers' graphic drawing skills for a socioscientific problem situation is suitable for an open-ended question. While developing the open-ended question used in the study, it was inspired by the SIR model as a socioscientific problem situation.

The open-ended question directed to prospective teachers is given in Figure 2.



While the coronavirus pandemic is happening all over the world, unfortunately, the first corona virus case was seen in the Dream country, which is a small country. In the dream country, there is no person who has not passed the corona in a period of 5 months. It is known that the epidemic peaked only once in the country and there were no other fluctuations in the epidemic. The good news is that in the dream country, no one died from corona during this process. It is known that the number of people recovering starts from the 3rd month of the process. The process was completed within 1 year in the Dream country, where vaccination, mutation, etc. did not occur.

• Number of people without corona (G)

• Number of people infected (Contagion) (E)

• Number of people recovering (İ)

According to the given, plot the number of people-time graph for the three groups of variables above, showing the 1 year general course of the epidemic from the beginning. Use the symbols provided to represent each group in the graph. After making your drawing, explain in detail how you drew the graph with verbal expressions.

Figure 2. Open-ended question directed to prospective teachers.

Considering that the graphics asked to be drawn in the question in Figure 2 depend on the proliferation of the Covid-19 virus, the rate of proliferation, transmission and decrease of the virus will not be constant with each passing day. Therefore, the graphs specified in the question should be drawn in a non-linear manner and taking into account the relations between each other. In the question given in Figure 2, it is stated that there is no person left without corona in the first five months. This expression indicates that the entire population is infected in the first five months. Therefore, the infection graph should start from zero (origin) and a rapidly increasing graph should be drawn to reach the population of the dreamland in the fifth month. Since the entire population is sick in the fifth month, the infection graph will start to decrease rapidly after this month and will be reset in the 12th month. Depending on this situation, the graph showing the number of people who did not have corona in the first five months should be drawn as the opposite of the infection graph, and a rapidly decreasing graph starting from the population of the Dreamland and zeroing in the fifth month. On the other hand, when considered within the natural framework of the process, the variable rate increase in the number of infected patients with each passing day necessitates the number of recovered patients. Because, according to the information given in the question in Figure 1, it is stated that there were no patients who died during this epidemic process, the number of those who recovered started in the third month of the process and was completed in the 12th month. For this reason, the graph of the number of people recovering will increase rapidly from the third month, as in the graph of infection, and reach the total population number in the 12th month. However, towards the end of the process, that is, closer to the 12th month, since the spread of the infection gradually decreases, there should be a downward bend in the graph of the number of patients who recovered, increasing and decreasing. Considering all this information, the correct graph to be drawn for the question in Figure 2 is given in Figure 3.

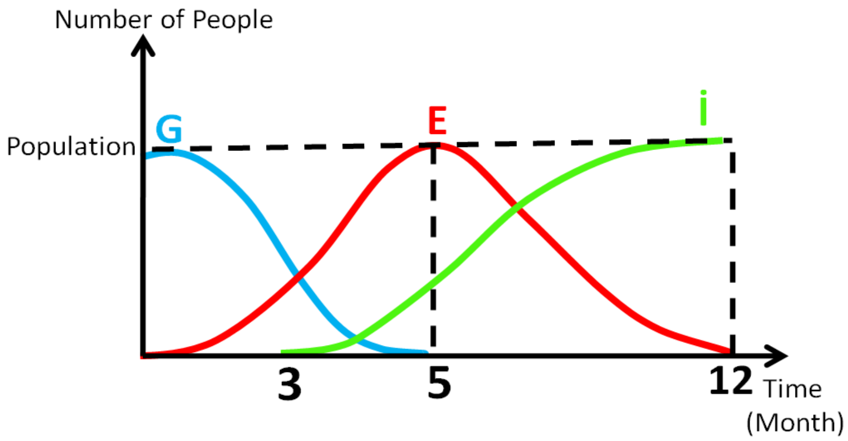


Figure 3. Correct graphic drawing for the open-ended question directed to prospective teachers.

2.3 Analysis of data

The graphs drawn by the prospective teachers were analyzed in two stages. First of all, the drawn graphics were scored according to the criteria in Table 1, which was inspired by the study of Beler (2009), and descriptive analysis was performed.

Table 1. Evaluation Criteria for the Graphics Drawn by the Prospective Teachers (Beler, 2009).

Evaluation Criteria	Categories	Point
Naming the Axes	**Correct:** The case where both axes are named correctly.	10
	Partially Correct: The case where only one of the axes is named correctly and the other is named incorrectly or not.	5
	Incorrect: Both axes are named incorrectly or both axes are not named.	0
Writing Data to Chart Axes	**Correct:** Correctly writing data on both axes.	10
	Partially Correct: Correct writing of data on only one axis.	5
	Incorrect: Data is written incorrectly or not written on both axes.	0
Starting the Graph Curve from the Appropriate Place	**Correct:** Starting the graphic curve from the desired point, reaching the peak value and ending it.	10
	Partially Correct: Not paying attention to at least one while starting the graphic curve from the desired point, reaching the peak value and ending it.	5
	Incorrect: Starting and ending the graph curve from any place that is not appropriate according to the given question.	0
Proper Continuation of the Chart Curve	**Correct:** Plot the entire graph curve in accordance with the question	10
	Partially Correct: Plotting a part of the graph curve in accordance with the question.	5
	Incorrect: Not plotting the graph curve in accordance with the question.	0

When scoring according to Table 1, the highest possible score is 100 and the lowest score is 0. After the descriptive analysis, the scores of the prospective teachers were ranked from the highest to the lowest. The goal here is to make it easier to group similar answers. Then, the answers in the determined groups and the errors made in the graph curves were examined by content analysis. In the content analysis, categories and codes were created. The styles adopted by the prospective teachers while drawing graphics formed the categories. The mistakes made by the prospective teachers in the drawing styles they adopted were content analyzed in a way to create the codes.

3 Findings

The answers given by the prospective teachers to the question of drawing graphs in the context of Covid-19 were scored according to the criteria in Table 1. The data regarding the scoring made are shown in Table 2.

Table 2. The Points of the Prospective Teachers from the Graphics Drawn by Them.

Categories	Prospective teachers	Points	f	%
Above Average Scores (f=25, %=58,14)	T_{35}	95	1	2,32
	T_{13},T_{27},T_{33},T_{41}	80	4	9,30
	T_{1},T_{3},T_{7},T_{15},T_{26},T_{28},T_{34}	75	7	16,27
	T_{10},T_{14},T_{17},T_{22},T_{23},T_{24}	70	6	13,95
	T_{16},T_{18},T_{25},T_{30},T_{32},T_{36},T_{43}	65	7	16,27
Below Average Scores (f=18, %41, 86)	T_{4},T_{9},T_{11},T_{20},T_{21},T_{31}	60	6	13,95
	T_{12}	55	1	2,32
	T_{19}	50	1	2,32
	T_{5},T_{37},T_{38},T_{40},T_{42}	45	5	11,62
	T_{29}	40	1	2,32
	T_{8}	30	1	2,32
	T_{39}	25	1	2,32
	T_{2},T_{6}	15	2	4,65

According to Table 2, the highest score obtained is 95, and the lowest score is 15. The mean score of the study group was calculated as 61.16. As a result of the scoring, it was seen that the prospective teachers who scored close to each other made similar drawings. However, since three related graphs were asked to be drawn in the problem situation, it was observed that they made similar mistakes in different graphs. This situation makes it difficult to present errors. However, the important points determined in order to draw the graphs according to the given problem situation helped to determine the errors and error sources. In order to draw graphs correctly, it should be known that time is a continuous data, and therefore, the graph should be drawn non-linearly by paying attention to the increasing and decreasing states depending on the critical values given in the question. As a matter of fact, it is seen that the mistakes made are concentrated in the mentioned cases. The data regarding the mistakes made by the prospective teachers are given in Table 3.

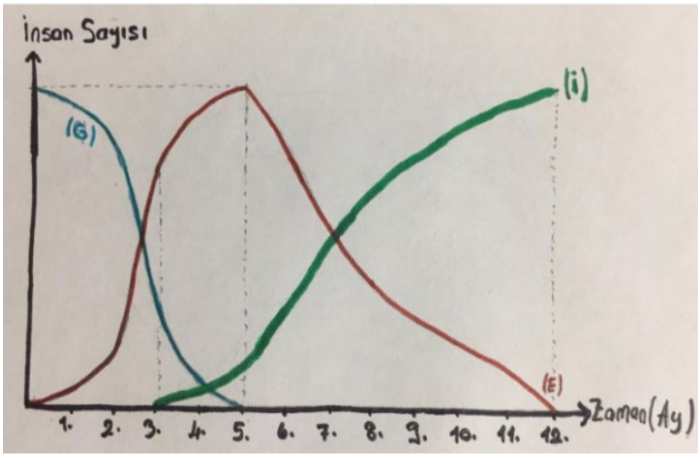
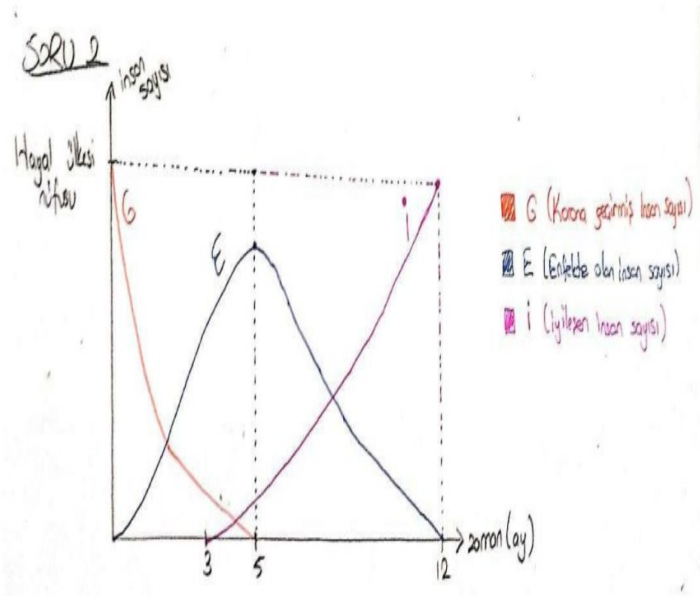
Table 3. Mistakes Made by Prospective Teachers in the Graphics They Drew.

Categories	Codes
Non-Linear Charts	Incorrect drawings made in the course of at most one graph Drawings made with an error in at least one of the critical values (start, peak and end points) Parabolic drawings
Linear Charts	Continuously increasing or continuously decreasing drawings Drawings with variable increase and decrease Drawings with scaling errors

When the drawings are examined, it is seen that the prospective teachers have adopted two different drawing styles as non-linear and linear graphics. Although the non-linear drawing style is a correct approach in the context of the question asked, some errors were also identified in the graphics of the prospective teachers who adopted this drawing style. For this reason, the errors in the graphics drawn by the prospective teachers were examined in two different categories as non-linear and linear graphics and coding was done. The coding for the mistakes made in the drawings made by the prospective teachers is given in Table 3.

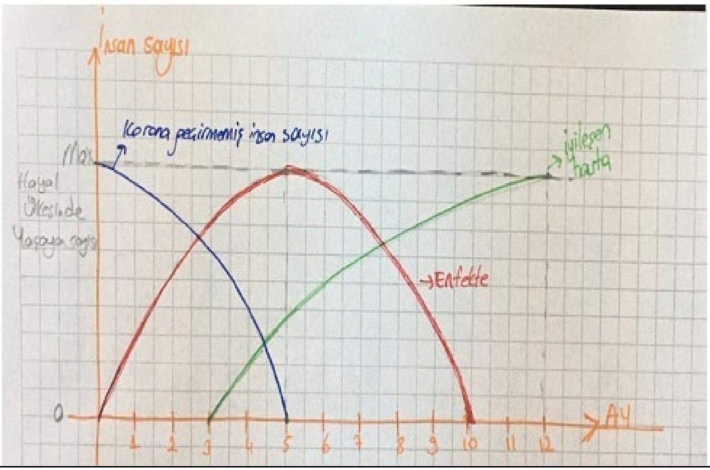
In order to better understand the coding made regarding the mistakes made in Table 3, some examples of the drawings made by the prospective teachers are presented in Table 4 and Table 5. Examples of incorrect drawings made by prospective teachers who prefer non-linear graphic drawing are given in Table 4.

Table 4. Examples of Incorrect Drawings Made by Prospective Teachers Who Prefer Non-Linear Graphic Drawing

Codes	**Incorrect Drawings**
Incorrect drawings made during the course of at most one graph.	**T35**: 
Drawings made with an error in at least one of the critical values (start, peak and end points)	**T28**: 

Parabolic drawings

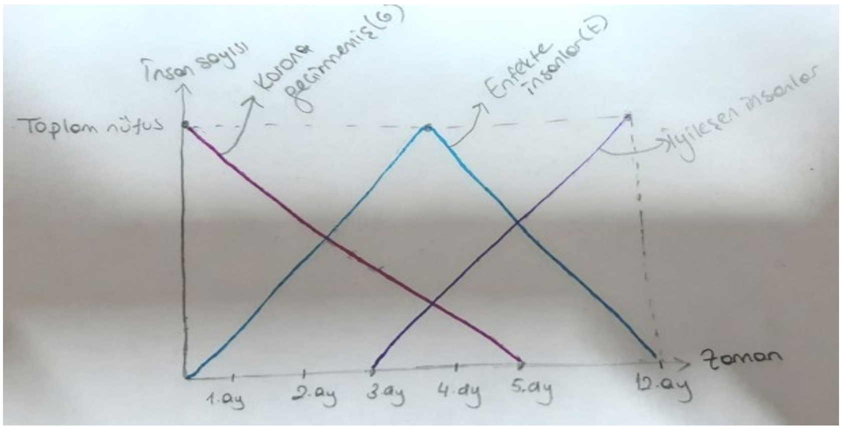
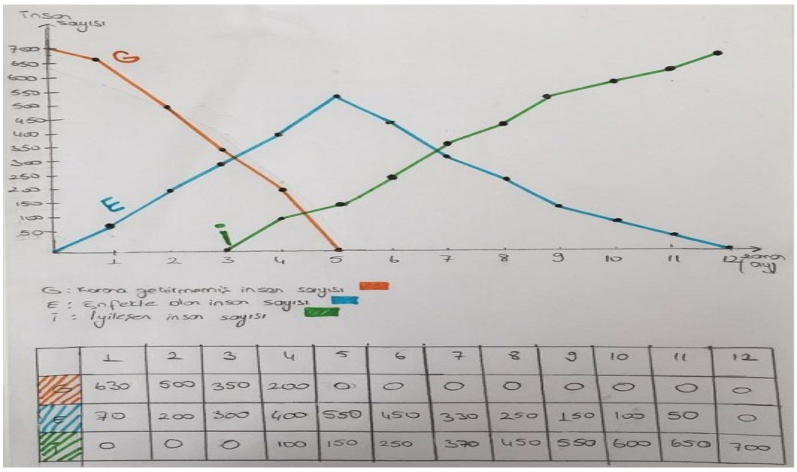
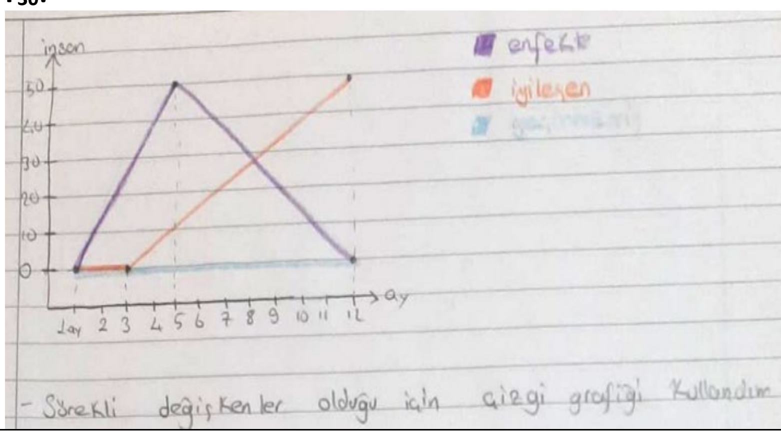
T_{14}:



When Table 4 is examined, it is seen that the first error type made by prospective teachers who prefer non-linear graphic drawing is the incorrect drawing made in during the course of at most one graph. The drawing made by T_{35} is given in Table 4 as an example of this error type. It is seen that T_{35} drew the closest to the correct answer by paying attention to the increasing and decreasing states of all critical values (start, peak and end points). However, it is seen that T_{35} draws a decreasing graph by accelerating after reaching the peak of the infection graph. However, just as the infection graph increased in the first five months and reached its peak, after the fifth month, the graph experienced a turning point and decreased in the same way, and the process should be completed in the 12th month. This situation indicates that an error was made in during the course of the infection graph. Another type of error made by prospective teachers in non-linear drawings is drawings where at least one of the critical values is incorrect. As an example of this incorrect drawing, the drawing made by T_{28} prospective teacher is presented in Table 4. When the graphs drawn by T_{28} are examined, there is no general error in during the course of the graphs. However, while the infection graph should reach the population of the country in the fifth month, it is seen that the drawing was made without paying attention to this information. The last type of error made by prospective teachers who prefer nonlinear graphic drawing is parabolic drawings. As an example of this incorrect drawing, the drawing made by the T_{14} prospective teacher is given in Table 4. Although it was stated in the question that the infection would peak in the fifth month and the process would be completed in the 12th month, T_{14} in his drawing started the infection graph starting from the origin, reached the peak value in the fifth month and finished it in the 10th month. This situation shows that the prospective teacher T_{14} thought that the process should end in the 10th month, which is symmetrical with respect to the peak, since the process reaches its peak in the fifth month. Therefore, graph drawings made in this way are coded as parabolic drawings.

Examples of incorrect drawings made by prospective teachers who prefer linear graphic drawing are given in Table 5.

Table 5. Examples of Incorrect Drawings Made by Prospective Teachers Who Prefer Linear Graph Drawing

Codes	Incorrect Drawings
Continuously increasing or continuously decreasing drawings	**T$_{18}$:** 
Drawings with variable increase and decrease	**T$_{17}$:** 
Drawings with scaling errors	**T$_{30}$:** 

When Table 5 is examined, it is seen that the first error type made by prospective teachers who prefer linear graphic drawing is linear drawings that are constantly increasing or constantly decreasing. The drawing made by T_{18} is given in Table 5 as an example of this error type. T_{18} drew attention to all critical values (start, peak and end points). However, it is seen that he cannot think that the infection process is progressing by increasing or decreasing at different rates day by day. For this reason, he preferred to make a linear drawing with a constant slope in all three graphs. Another error type is linear drawings with variable increase and decrease. As an example of this incorrect drawing, the drawing of T_{17} is given in Table 5. T_{17} created a data set by paying attention to the critical values in the question to draw the graph. Although he discovered that the process was increasing and decreasing at different rates day by day in the drawings he made with this data set, he made linear drawings because he thought of the time variable as a discrete data. It can be said that incorrect drawings made in this way are caused by approaching the graph on a point basis. The last type of error made by prospective teachers who prefer linear graphic drawing is scaling errors. In the drawing of T_{30} given in Table 5, the graphs not starting from the origin and marking the zero point from above can be shown as an example of this error.

4 Discussion, conclusion, and suggestions

When the graphs drawn by the prospective teachers regarding the Covid-19 pandemic process, which is presented as a socio-scientific problem situation, are scored according to the determined criteria, it is seen that the highest score is 95, and the lowest score is 15. The mean score of the study group was calculated as 61.16. It was determined that 58.14% of the study group got a score above the average and 41.86% of them got a score below the average. In addition, it is seen that none of the prospective teachers could get full points (100). The fact that the rates of scoring above and below the average are close to each other and that none of the prospective teachers could get a full score suggest that there are significant deficiencies in the prospective teachers' graphic drawing skills. As a matter of fact, in many studies in the literature related to graphics, it is stated that the area that prospective teachers have the most difficulty is drawing graphics (Bayazıt, 2011; Ercan, Coştu, & Coştu, 2018). When the graphic drawings of the prospective teachers are examined in detail, it is seen that they draw linear and non-linear graphs. It is necessary to know that time is a continuous data in order to draw the graphs for the given problem situation correctly. In addition, the graph should be drawn non-linearly by paying attention to the increasing and decreasing states of the critical values given in the question. When the answers of the prospective teachers who draw non-linear graphs close to the correct answer are examined, it is observed that they know that time is a continuous data and the number of people is a discrete data. As the most important indicator of this situation, it can be thought that prospective teachers who draw non-linearly draw processively by writing only the critical values given in the problem situation, without creating any point data. It can be said that the drawings made in this way are at the level of qualitative (global) perception. As a matter of fact, according to Bayazıt (2011), graphic drawings that require qualitative perception are drawings made using relationships between graphics without showing a point approach. In this study, when graphs are drawn considering the relationship between the number of people who have not had the disease, infected and recovered, it is obvious that all graphs will not be linear. Graphs can be drawn accurately by discovering the interdependent increase and decrease states. It is observed that prospective teachers who do not adopt a linear drawing style achieve this. However, it is observed that they experience difficulties in some critical values and in cases such as accelerated decrease or increase. As a matter of fact, this situation is also seen in the drawing of the only prospective teacher (T_{35}) who gave the closest answer to the correct answer. For this reason, focusing on activities that contribute to qualitative thinking in graphic drawing teaching can provide important benefits in eliminating these problems.

On the other hand, when the drawings of the prospective teachers who make linear drawings are examined, it can be said that they approach graphic drawing on a point basis on the basis of their mistakes and they are not aware that time is a continuous variable and the number of people is a discrete variable. It can be said that the drawings made in this way are the drawings at the level of quantitative (global) perception. According to Bayazıt (2011), graphic drawings that require quantitative perception are drawings created by marking a tabular data set on the analytical plane and connecting the points. This situation can be seen in the drawings of T_{30} and T_{17}, who made linear drawings in the study. In particular, the fact that T_{17} prospective teacher created a data set that was not given in the question and adopted a graphic drawing in this way caused him not to realize that time is a continuous variable and to make a linear drawing. It was also observed that prospective teachers made continuously increasing or decreasing linear drawings and scaling errors. This finding is in line with the results of studies in the involved literature (Bayazıt, 2011; Dunham & Osborne, 1991; Gültekin, 2014; Leinhardt, Zaslavsky, & Stein, 1990). Technology-supported activities (dynamic software, desmos, graph calculators, etc.) that facilitate the process approach and provide visualization can be used in teaching in order to prevent such errors that can be caused by approaching graphic drawing on a point basis. As a matter of fact, some studies in the related literature show that dynamic software increases mathematical success by providing visualization (Çetin, 2017; Sheehan & Nillas, 2010).

It is thought that the approaches and mistakes of the prospective teachers while drawing graphics, determined within the scope of this study, are important. The errors detected in the studies on graphics at various grade levels and the mistakes of the prospective teachers identified in this study are similar. This situation makes us think that the mistakes made about the graphics continue up to the advanced education levels. Therefore, while teaching graphics, it is necessary to eliminate the existing misconceptions and to plan the teaching in a way that does not cause misconceptions. While planning activities or instruction for teaching graphics, first of all, students should be made to feel their own misconceptions by asking various questions about the misconceptions identified in this study. Then, in order to eliminate these misconceptions, instruction should be planned with activities that require both quantitative (pointwise way) and qualitative (global way) thinking. Especially in most teaching activities in primary and secondary schools, it is tried to teach graphic drawing by giving limited point data and making markings on the coordinate plane. This situation causes students to approach graphics from a limited pointwise way (quantitative) perspective. However, both pointwise way (quantitative) and global way (qualitative) point of view are important in graphic drawing. For this reason, while teaching graphics, multi-faceted activities that require quantitative and qualitative perspectives should be used.

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