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# THEORY AND LAW: MYSTERY LINES ACTIVITY[1]

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## ABSTRACT

This study aimed to teach 9th grade students the meanings of scientific theory and scientific law, and the differences between them. The related literature informs that students at different grade levels have misconceptions about the definition of both scientific theory and scientific law and the relationship between them. In this study, the teaching activity emphasized that the characteristics of scientific theory and scientific law are different. The activity was carried out in five groups, each with 5 students forming a sample of 25 students. The first part of the activity emphasized that scientific laws are in fact the simplest form of relations and generalizations. The second part focused on scientific theories emerging from inferential explanations. This activity is important in terms of supporting conceptual understanding of the students and teaching that scientific theories and scientific laws are different kinds of information and that scientific knowledge are open to change.
**Keywords:** scientific literacy, nature of science, theory, law, mystery lines.

# TEORİ VE KANUN: GİZEMLİ DOĞRULAR ETKİNLİĞİ

## ÖZ

Bu çalışmayla ortaöğretim 9. sınıf öğrencilerine, bilimsel teori ve bilimsel kanunun ne olduğu ve aralarındaki farkların neler olduğunun, açık düşündürücü bir etkinlikle öğretilmesi amaçlanmaktadır. İlgili alanyazın incelendiğinde sadece ortaöğretim düzeyinde değil, birçok öğrenim seviyesinde öğrencilerin bilimsel teori ve bilimsel kanunun gerek tanımları gerekse aralarındaki ilişki konusunda kavram yanılgılarına sahip oldukları görülmektedir. Bu bağlamda, bu çalışmada gizemli doğrular etkinliği ile bilimsel teori ve bilimsel kanunun yapısal özelliklerine ve farklı türden bilgiler olduğuna vurgu yapılmaya çalışılmaktadır. Gizemli doğrular etkinliği, çalışma grubunu oluşturan 25 öğrenciyle ve bu öğrencilerin 5'erli 5 bilim insanı takımı oluşturmalarıyla iki bölüm halinde yürütülmüştür. İlk bölümde bilimsel kanunların aslında en yalın biçimiyle ilişkiler, genellemeler, eşitlikler, bağıntılar olduğu; ikinci bölümde ise bilimsel teorilerin, çıkarımsal açıklamalar üzerinde yoğunlaştığına odaklanılmaktadır. Bu etkinliğin öğrencilerin hem kavramsal anlamalarının sağlanmasında hem de bilimin doğasının bilimsel teoriler ve bilimsel kanunlar farklı türden bilgilerdir ve bilimsel bilgi değişime açıktır unsurlarının öğretimi açısından önemli olduğu düşünülmektedir.
**Anahtar kelimeler:** bilim okuryazarlığı, bilimin doğası, teori, kanun, gizemli doğrular.

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## INTRODUCTION

Individuals who produce, process, and use knowledge play important roles in the development of societies (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 2012). These individuals are science literate. Scientific literacy is defined as curiosity about world, producing logical solutions to events, participating in cultural and civil events, knowing and understanding the scientific concepts and methods necessary for making personal decisions, and has formed the vision of many curricula in recent years (AAAS, 1993; Ministry of National Education [MoNE], 2006; 2013; 2018a; NRC, 2012). As mentioned in many curricula, the nature of science is an important component of scientific literacy (Driver, Leach, Millar, & Scott, 1996; Thomas & Durant, 1987). The nature of science is a hybrid field that focuses on what science is, how it works, the epistemological and ontological foundations of science, and the scientific and social interactions of scientists. (Clough, 2006; Herman, 2010; McComas, Clough, & Almazroa, 1998; Özcan, 2013). The nature of science can be better understood by the knowledge of fundamental elements such as interchangeability, experimentation, observation and inference, theory and law, imagination and creativity, and social and cultural influence.

The current research is based on the understanding that *scientific theories and scientific laws are different kinds of knowledge*. It aims to understand what scientific theory and scientific law is and aims to do a thought-provoking teaching with a planned activity to understand the difference between them (Lee & Fortner, 2007). When the literature is examined, the studies suggest that many students have misconceptions such as "*scientific law is more important than scientific theory*", *"scientific theory can change, but the scientific law never changes", and "the scientific law presents the proven knowledge and ultimate fact."* These misunderstandings make the current research important and necessary (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & BouJaoude, 1997; Jain, Abdullah, & Lim, 2016; Lee & Fortner, 2007; McComas, 2004; Schwartz, Lederman, & Crawford, 2004; Stefanidou, Skordoulis, & Kechagias, 2018). Teaching scientific law plays an important role in improving the students' conceptual understanding of science. In addition, it is important to emphasize the following two elements of the nature of science: *"scientific theories and scientific laws are different kinds of knowledge"* and *"scientific knowledge is open to change"* (Abd-El-Khalick et al., 1998; Abd-El-Khalick & BouJaoude, 1997; Lee & Fortner, 2007; McComas, 2004; Schwartz et al., 2004). The activity designed in the current research had two parts. The first part stressed that scientific laws are actually the simplest form of relations, generalizations, and equations whereas the second part emphasized that scientific theories focus on inferential explanations (Abd-El-Khalick et al., 1998; Abd-El-Khalick & BouJaoude, 1997; Lee & Fortner, 2007; McComas, 2004; Schwartz et al., 2004).

The activity used in this study was developed by Lee and Fortner (2007) and adapted to Turkish by Özcan (2013). In this study, the Turkish version of the activity was used. The study was conducted with 25 ninth grade students in a science high school where the concepts of theory and law were included in the curriculum. Necessary permissions were obtained from the National Education Directorate to conduct the research. Science high schools aim to educate students as scientists in the fields of science and mathematics (MoNE, 2013). Related to scientific theories and scientific laws, the science high schools curriculum explains that science teaching intents for students of science high schools "to learn the concepts, theories and laws in accordance with their academic levels; use the mathematics field knowledge by analyzing the events in more depth; follow developments in science, technology and technological products and produce innovative projects." (MoNE, 2018b, p.11). In addition, the ninth grade physics textbook prepared for science high schools elaborates that the aim of Physics is "to clarify the events in the universe, to express the relationship between matter and energy with equations. These equations are referred to as 'laws' in physics... Constructs theories for future experiments and observations." (Aydın et al., 2018, p.14).

## ACTIVITY IMPLEMENTATION

The activity starts with forming five voluntary scientist teams [STs], identifying a team leader and arranging group seating in the classroom. The two-part activity was carried out using the activity worksheets given in the appendix, and in the first part, Figure 1 and the tasks of scientists are explained in detail. According to this, the students are asked to imagine the mystery lines in Figure 1 and to assume that they are at the point O. Then they are told that there are lines at different distances and different lengths from each other as shown in Figure 1. These lines are called Mystery Lines and as scientists they must follow this mystery.

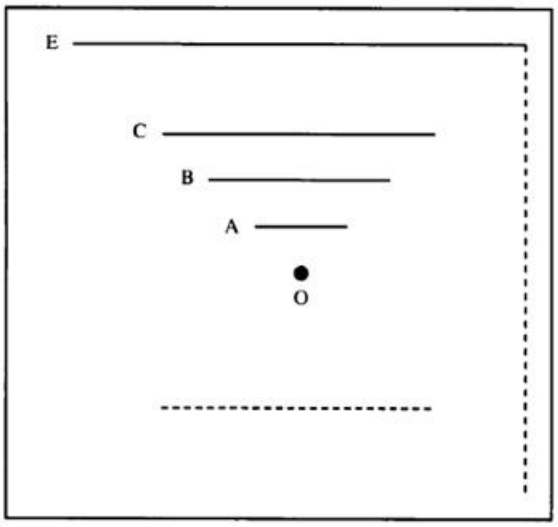
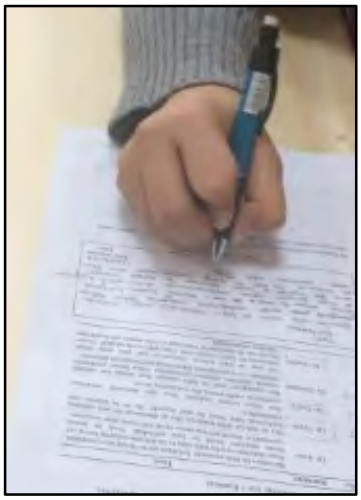



**Figure 1.** Mystery Lines

Stundents are asked to measure the distance of mystery lines to the point O, the length of each line, and record the data in the "Values according to the point O" table (Photograph 1). Based on the data they obtained, they are asked to respond to the five questions in the activitiy worksheet.

**Photograph 1.** STs' Work on Mystery Lines

In the second part of the activity, the cards that include the character definitions in "Five characters for Role-playing" Table in the worksheet are distributed to the students. Each student takes at most two cards. Students are then asked to imagine what they would discuss about mystery lines at a conference as scientists. They are also told that although they think Law of Line is interesting, they do not know how it is formed. Students develop their own theories using the cards and explain how they formed their theories by dicusssing with other scientists in their groups. Then, students write a letter to other scientists to explain the theory they have developed (Photograph 2).



**Photograph 2.** STs are Writing Letters to Other Scientists

After the activity, the letters written to the scientific community are shared with other scientists and read loudly in the class. Students explain their therioes by giving examples from the history of science by referring to the differences between theories and laws. The activity ends with a whole class discussion.

### Tools and Equipment

The activity is easy to implement and it mostly uses the activity worksheet. The tools needed for the activity are as follows:

- Activity worksheet
- Computer
- Projector
- Pencil
- Eraser

## FINDINGS

Activity worksheet starts with instructing students to form groups and then introducing them to the mystery lines. The fourth instruction of the worksheet is in fact a warm-up question and asks students to calculate the lengths and distance of the lines to the point O. Table 1 presents these values. All measurements are in centimeters (cm).

**Table 1.** Measurements of STs to the Imagined Point O

| Team | Line Names | Distance | Length |
|---|---|---|---|
| Space | A | 0.7 | 1.3 |
| | B | 1.4 | 2.6 |
| | C | 2.1 | 3.9 |
| | D | 2.8 | 5.2 |
| | E | 3.5 | 6.6 |
| | F | 4.2 | 7.8 |
| | J | 7 | 13 |
| Nameless | A | 0.75 | 1.25 |
| | B | 1.25 | 2.5 |
| | C | 2 | 4 |
| | D | 2.75 | 5.25 |
| | E | 3.25 | 6.5 |
| | F | 3.25 | 6.5 |
| | J | 0.75 | 1.25 |
| Limitless | A | 0.62 | 1.3 |
| | B | 1.24 | 2.6 |
| | C | 1.86 | 3.9 |
| | D | 2.48 | 5.2 |
| | E | 3.10 | 6.5 |
| | F | 3.72 | 7.8 |
| | J | 4.34 | 9.1 |
| Refined | A | 0.7 | 1.3 |
| | B | 1.4 | 2.6 |
| | C | 2.1 | 3.9 |
| | D | 2.8 | 5.2 |
| | E | 3.5 | 6.5 |
| | F | 4.2 | 7.8 |
| | J | 7 | 13 |
| Technologists | A | 0.7 | 1.3 |
| | B | 1.4 | 2.6 |
| | C | 2.1 | 3.9 |
| | D | 2.8 | 5.2 |
| | E | 3.5 | 6.5 |
| | F | 4.2 | 7.8 |
| | J | 4.9 | 9.1 |

Table 2 shows the responses of STs to the first question of the activity worksheet: How far are the lines to the point O and how long is each line? In their responses to this question, the students explained the patterns they recognized about the structure of the lines in Figure 1.

**Table 2.** The Responses of STs to the First Question of the Worksheet

| Team | Patterns |
|---|---|
| Space | Distance and length are going up by about two times. We can say that the length is 2 times the distance. |
| Nameless | The distance and length to the point O is increasing evenly. Firstly, a triangle shape appeared. When we continued the measurements, we saw that nested squares were formed, and from the top it looked like a pyramid |
| Limitless | The length of each line increases as it moves away from the point O. There is a certain level of increase. |
| Refined | The line consists of 2 layers of triangles and proportions. |
| Technologists | The distance of the lines from one another is increased by one unit and the lengths are divided into two units. |

Table 3 presents the responses of the scientist teams to the second question of the activity worksheet: If there was a line D, where would it be according to the pattern? Table 4 presents the responses to the third of question of activity worksheet: If the $10^{th}$ line were the line J, what would be the length and distance of line J to the point O?

The responses of STs to the fourth of question of acitivity worksheet is presented in Table 5. The fourth question was formulated as “If there were many other lines, for instance, where would the $20^{th}$ and $50^{th}$ line be? What would their length be? And what would their distance be to the point O?”

**Table 3.** The Responses of STs to the Second Question of the Worksheet

| Team | Explanation |
|---|---|
| Space | It would be between C and E. Its distance would be 2.8, its length would be 5.2 cm. |
| Nameless | When we look at the proportions, we think it will be placed between C and E. The lines are getting shorter. The length of D would be 5.25 cm and the distance to O would be 2.75 cm. |
| Limitless | Being between the C line and E line makes the measurements more consistent. Therefore, the distance would be 2.48, the length would also be 5.2 cm. |
| Refined | Located between C and E. Its distance to the O point would be 2.8 and its length would be 5.2 cm. |
| Tech. | The line D would be after C and before E, its length would be 5.2 and its distance would be 2.8 cm. |

**Table 4.** The responses of STs to the Third Question of the Worksheet

| Team | Patterns |
|---|---|
| Space | Length 7, Distance 13 cm. |
| Nameless | We thought that the line J was equal to point A and at the bottom of O point. We have identified the same physical properties with A except for location. |
| Limitless | The distance would 6.2 and the length would be13 cm. |
| Refined | The distance would 7 and the length would be13 cm. |
| Tecnologists | The distance of J line is 4.9 cm and length is 9.1. |

**Table 5.** The Responses of STs to the Fourth Question of the Worksheet

| Team | Explanation |
|---|---|
| Space | The distance of the $20^{th}$ line to point O is 14 and the length is 20 cm. The distance of the $50^{th}$ line to point O is 26 and the length is 65 cm. |

**Table 5** (continued)

| Team | Explanation |
|---|---|
| Nameless | As in the line J, the length of the lines will continuously increase from A to E. Since it progresses from E to J, it will change its dimension continuously. |
| Limitless | The distance of the $20^{th}$ line is 12.4 and its length is 23 cm and the distance of the $50^{th}$ line is 31 and its length is 65 cm. |
| Refined | The distance of the $20^{th}$ line would be 14 cm to point O and the lenghth would be 26 cm. The distance of the $50^{th}$ of line to point O would be 35 cm and the length would be 65 cm. |
| Technologists | The distance of the $20^{th}$ line would be 14 cm and the length would be 26. The distance of the $50^{th}$ line would be 35 cm and the length would be 65 cm. |

**Table 6.** The Responses of STs to the Fifth Question of the Worksheet

| Team | Explanation |
|---|---|
| Space | The length is two times the distance. If x is the distance, the length becomes 2x. An equilateral triangle appears. |
| Nameless | The length of the line is 2 times (a = 2b) of the distance from point O. Here, the shape of the pyramid is reduced in proportion to the overlapping squares. |
| Limitless | There are also symmetric equivalents of the lines we measured. They can exist in all four directions. |
| Refined | The results of the measurement and the resulting pattern are progressing in a certain ratio and order. The length is 1.3 and the distance is 0.7 cm. |
| Technologists | The distance between the lines is in the form of a pattern and proportional and is similar to the equilateral triangle. This ratio is x = 1/2. |

Table 6 presents the responses of STs to the fifth question of the worksheet on mathematical expression of the pattern. Based on the five questions in the worksheet, a final question was posed to the students. Table 7 presents the reponses of STs to this question which was the focus of the activity: Assume that you named the relationship as Law of Line. No matter how far the line goes away, why does it fit into this law?

**Table 7.** The Responses of STs to the Final Question

| Team | Explanation |
|---|---|
| Space | This aligns with the law because there is a fixed rate between the lines. |
| Nameless | The length of the line is increasing to a certain limit. When it reaches the boundary, the proportions of the lines decrease. The result is continuity. |
| Limitless | As a result of the measurement of the given lines, the lines appear to be within a certain standard. It is assumed that the value of every new line added to the universe has increased. Measurements also support this. |
| Refined | Since the lines are formed with a certain length and distance ratio, this ratio does not change even if it goes forever but it complies with Law of Line. |
| Technologists | The lines are arranged according to a certain ratio. The lengths are increasing as they move away from us. Therefore, they comply with this law. |

The theories developed by the team members are explained by a letter to the scientific community. These letters are shared in Figures 2-10. Each student is represented by Letter S.

*According to Dr. Line, Lines form triangles as they move away from where we stand. These triangles form the square. If we assume that there is a force surrounding our world, this force creates squares. I called it K-Square.*

*Sincerely*

**Figure 2.** The Letter Written by S-4

*I agree with Dr. Squares. I argue that the world consists of squares in the form of layers of atmosphere. My reason is as follows: If we accept the world as the most internal square, it represents the other squares in the other layers. There are forces linking these squares. Due to the proportionally increasing squares, the attraction force between the layers of the world is increasing. If the world was round, there would be imbalance in the movement of the world. Because the world is square, its movements are regular. I named the theory as a layer gravity.*

*Sincerely*

**Figure 3.** The Letter Written by S-5

*I am Dr. Line who discovered Law of Line. The length of the lines increases as they move away from where we live. When I examined several opinions about the shape of our world, I would like to express that I agree with Dr. Triangle's opinion. These lines will also increase when the lines are drawn into a triangle. I name my theory as Line-triangle.*

*Sincerely*

**Figure 4.** The Letter Written by S-21

*I believe that that line lenghts increase as they move away from where we live, as Dr. Line argues. However, these lines constantly repeat this. Therefore, I partially agree with Dr. Line's theory. I have continued my resarch following the work of Dr. Triangle. Inspired by this, I named by theory 3Gen Squares.*

*Sincerely*

**Figure 5.** The Letter Written by S-11

*My name is Dr. Squares. I partially agree with Dr. Square. Based on my research and measurements, I came to the conclusion that there was a consistent and logical relationship about the distance and length between the first line and the following lines. This shows that Dr. Line's theory is correct but not complete. I call my theory Infinite Squares.*

*Sincerely*

**Figure 6.** The Letter Written by S-3

*I am Dr. Dotted. I have observed that there are dotted lines in two different directions. I think there are dots that can't be seen. The dots we see are part of them. I realized that the lines formed triangles when I reviewed the previous research. There is a force that holds these triangles together. Otherwise the triangles move and the come together to form squares. Apart from these squares, there is a big square that covers these squares. I name my theory "s-triangle."*

*Sincerely*

**Figure 7.** The Letter Written by S-22

*I am Dr. Square. I think there is a force surrounding our world. I also agree with Dr. Line and argue that lengths of lines increase as they move away from where we stand. I name my theory as Great Square Theory*

*Sincerely*

**Figure 8.** The Letter Written by S-15

*Observing that the lines move along equally, we argue that our triangle represents the center of the earth and that every line is a layer. Our argument aligns with that of Dr. Triangle and Dr. Line. The name of my theory is From Lines to Triangles.*

*Sincerely*

**Figure 9.** The Letter Written by S-20

*I am Dr. Triangle. I believe that our world is in the shape of square. As a result of my work I have found that this triangle shape of the Earth consists of lines. Dr. Square's research also supports me. I can say that the world is made up of four triangles. These triangles combine to form a square. I called my theory three-square.*

*Sincerely*

**Figure 10.** The Letter Written by S-18

In the activity worksheet, there was an assessment question. Table 8 presents the students responses to this assessment question: "What do you think you have learned about **science** when you consider the activity process?" This question aims to understand the outputs of the process and evaluate the activity. Table 8 also presents how the responses are related with the elements of nature of science.

**Table 8.** The Relationship between the Activity and the Elements of Nature of Science

| |
|---|
| *I learned that any scientific knowledge can change. (S12-Changeability)* |
| *The only thing that remained unchanged was the change. (S21- Changeability)* |
| *The law could change (S2, S15-Changeability-Theory and Law)* |
| *Theory is not less reliable. (S3-Theory and Law)* |
| *Theory and law are closely related, but their sequence can change. (S7- Theory and Law)* |
| *It was not a bad thing that scientific knowledge remained in theory. (S11- S15-Theory and Law)* |
| *Not every proven theory becomes a law (S18-S22- Theory and Law)* |
| *The theory could come after the law (S20-Theory and Law)* |

## CONCLUSION and SUGGESTIONS

This study aimed to teach scientific theory and scientific law conceptually with an activity-based teaching and to support students' meaningful learning. Therefore, it was planned and carried out within the scope of the ninth grade physics lesson curriculum aims. According to the results of the activity, significant changes were observed in the opinions of the students. The ideas that "theory is more important than the law and this order never changes", "if the law is proved, the law becomes unchanged", "if it is not proved, then it becomes a theory" have changed. These ideas have been replaced by the ideas that theories are the implications for explaining our world, and theories may not become law, but

can be accepted academically as it will explain them. Some of the views that align with the literature are as follows (Abd-El-Khalick et al., 1998; Abd-El-Khalick & BouJaoude, 1997; McComas, 2004; Schwartz et al., 2004):

- Laws are based on equality, generalization, and relations rather than explanations.
- Not every theory necessitates theory.
- Both theory and law must be compatible with evidence.
- Scientific knowledge, whether theory or law, is testable.
- Scientific laws and scientific theories are different kinds of knowledge.
- Laws and theories cannot proceed by following a hierarchical sequence.

This study suggests that more thought provoking activities should be done for students to comprehend the nature of science. In this respect, new technology-science-based and material-supported activities can be designed in relation to scientific theory and scientific law components of the nature of science within the scope of curricula. The activities should be content-based rather than generic to provide meaningful learning. These activities might be enriched with interactive short stories that emphasize the nature of science. Furthermore, the pilot studies of the activities should be carried out with a group equivalent to the actual group. Participants should be informed about the activity. In this context, the research plan to be followed during the research should be shared with the participants before the research.

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Appendix

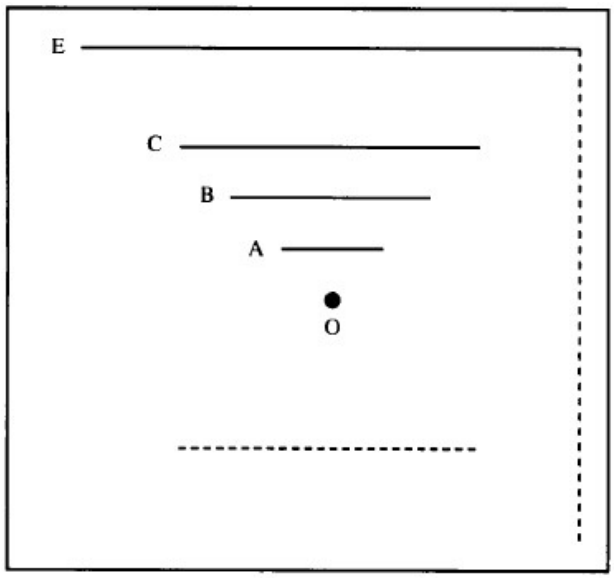
The Mystery Line Activity Worksheet

| **Name of the Team:** | **Names of the Scientists:** |
|---|---|

**Instructions**

1. Form scientist teams of 4 or 5 people.
2. Imagine that the point where you live is the point O in the world of mystery lines as shown in the Figure below.
3. As you observe in the figure, there are lines at different distances and lengths outside where you live. We call them Mystery Lines. Are you ready to go after this mystery as a scientist now?
4. As a scientist, you have to measure how far these Mystery Lines are to the point O and how long each line is. Fill out the "Values according to the point O" Table and answer the questions.

**There you go!**




Mystery Lines

## Questions

1. What pattern did you find between distances to the lines and lengths of the lines?
2. Line **D** is not shown. If there were a line **D**, what would its distance and its length be?
3. If the $10^{th}$ line were line J, what would be the distance of J to the point **O**?
4. If there were more lines in the figure, for example, where would the $20^{th}$ and $50^{th}$ line be; how far would they be from the point O, and what would be their length?
5. Describe the pattern you have discovered. Derive a mathematic equation if necessary.

Values according to the point O

| Name of Line | Distance | Length |
|---|---|---|
| A | | |
| B | | |
| C | | |
| D | | |
| E | | |
| F | | |
| J | | |

## Answers

**1.**.....
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**2.**.....
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**3.**.....
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**4.**.....
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**5.**.....
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The name of the relationship you find is the **Line Law**. According to this law, why does a line, no matter how far it goes away, fit this law?

**As a result, you have made a great discovery, congratulations!! But..**

Create your own theories by selecting one or two of the five characters in the table below. Discuss your theories with other characters in your team. Explain your theory to the scientific community using the letter template.

**Five characters for Role-playing**

| No | Characters | |
|---|---|---|
| 1 | Dr. Square | I am a prominent scientist. I have already published a well-known theory. I think our world has a shape and that there is a force that keeps our world in shape. Our world must be a huge square and we are located inside in the square. I call my theory The Great Square Theory. |
| 2 | Dr. Triangle | I am also a renowned scientist and I agree that our world has a shape. But I believe it is a triangle, and our place is on the pinnacle of the triangle. |
| 3 | Dr. Line | I discovered the Law of Line. The lines we observe are getting longer as they are getting farther away from us. |
| 4 | Dr. Dotted | I observed around our place and found something like a line (dotted lines in datasheet) in two different directions. I think that they are parts of invisible lines or remnants of lines. |
| 5 | Dr. Squares | I am a young scientist. I agree with Dr. Square's thought of a square shaped world. But I think there are many squares. Outside one square, there is a bigger square, and so on. |

Date: _____

Dear Colleagues,

Sincerely Yours,

Signature

Letter Template

Assessment Question: What do you think you have learned about **science** when you consider the activity process? Explain.

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