Prospective physics teachers' ideas and drawings about the reflection and transmission of mechanical waves

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Abstract
It is known that most of the students have difficulties in understanding the behaviour of a mechanical wave at a boundary. Being aware of the students' misconceptions about the subjects mentioned above can lead to the development of more effective teaching material on the topic of Vibrations and Waves. In this study, in order to reveal students' ideas about the subject, a test containing questions with drawings has been developed. The test was applied to 147 prospective physics teachers attending a state university in Türkiye, and interviews have been carried out with 21 students. The results have shown that the students had certain misconceptions and inadequate information about the subject. In the view of the results, some suggestions were made about teaching the subject.

Keywords: Physics education, Misconceptions on reflection of mechanical waves, Misconceptions on transmission of mechanical waves.

Resumen
Es conocido que la mayoría de los estudiantes tienen dificultades en comprender el comportamiento de una onda mecánica en una frontera. El estar consciente de las ideas erróneas de los estudiantes sobre los temas antes mencionados puede llevar al desarrollo más eficaz de material didáctico sobre el tema de Vibraciones y Ondas. En este estudio, con el fin de revelar las ideas de los estudiantes sobre el tema, se ha desarrollado una prueba que contiene preguntas con dibujos. La prueba se aplicó a 147 futuros profesores de física que asisten a una universidad estatal en Türkiye, y las entrevistas se han llevado a cabo con 21 estudiantes. Los resultados han demostrado que los estudiantes tenían ciertas ideas erróneas e información inadecuada sobre el tema. En vista de los resultados, se hacen algunas sugerencias sobre la enseñanza de la materia

Palabras clave: Physics education, Misconceptions on reflection of mechanical waves, Misconceptions on transmission of mechanical waves.

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I. INTRODUCTION

Researches indicate that students come to the science classroom with a number of naive conceptions which can inhibit the learning and understanding of certain concepts. Many of these misconceptions are widespread and have a detrimental effect on problem solving, course performance, and conceptual understanding of the material. These naive conceptions also appear to be resistant to change via traditional instructional approaches [1]. In this article, "misconception" refers to beliefs students have that contradict accepted scientific theories [2].

In order for students to change old ways of thinking, they must be willing to go through a series of conceptual changes. They must be either dissatisfied with their existing understanding, or they must be aware of contradictions and reconcile them accurately [3]. And for this, first of all, it is necessary to be aware of the students' ideas, to reveal the thought processes they used, and to understand how they departed from the modern scientific principles. This knowledge informs us about the difficulties that the students encounter and provide a foundation for preparing constructive and more efficient educational materials [4]. For these reasons, for many years, physics education researchers have worked on the students' understanding about special subjects such as mechanics, electrical circuits, heat, and temperature [5].

Witmann [5, 6], Witmann, Steinberg and Redish [7], Kaya Sengören, Tanel & Kavcar [8] and Tanel, Kaya Sengören & Kavcar [9] carried out studies to determine and eliminate student's misconceptions related to propagation and superposition of mechanical waves. Witmann [6] found the following misconceptions about reflection of mechanical waves from a boundary such that the wave bounced as a particle, that is to say, in which side of the rope it was, it reflected in the same side, or the pulse was damped on free or constant end. Moreover, he stated that most of the students had difficulties with the subject of reflection at the free end. Ambrose [10] found that the ability to relate the relative wave speeds and widths of the transmitted and incident pulses was difficult after standard instruction at both the introductory and the advanced level. As a result of the answers obtained from the question in which students were asked to draw the shape of two connected ropes after a certain time, where the propagating velocities of the pulses on two connected ropes were given relative to each other, he found that many students: (i) had failed to recognize that reflection would occur at a junction between two regions of different wave speed and (ii) had failed to relate the widths of the incident and transmitted pulses to the wave speeds. Ambrose [10] reported that students often said that a pulse approaching a different spring with greater wave speed would be completely transmitted. These students often articulate the idea that reflection only occurs when the incident pulse experiences "resistance" at the boundary. For many students, this "resistance" occurs only when the pulse is incident on a different spring with smaller wave speed. The task of drawing the transmitted pulse was proven to be difficult for all students, including graduate students, and the most common error was to indicate that the transmitted pulse had the same width as the incident pulse.

Subjects such as the reflection and transmission of the pulse in the boundary of another medium are the main subjects of the course of vibrations and waves. The reflection and transmission events on ropes or spiral springs look like the light being reflected and refracted at the same time. Having learned the subjects which can be understood more perceptible such as the transmission, and reflection of mechanical waves without misconceptions will make the optical subjects, which will be taught later, easier to be understood. Being aware of the misconceptions about the related subjects of the physics education students, who will be the high school teachers of the future, is the preliminary step to achieve the works intended to eliminate these misconceptions. Tao and Gunstone [11] were stated that students' conceptual change was context dependent and unstable. Palmer [12] also said that students were contextually dependent in their ideas (about gravity). Therefore, the researches related to students' misconceptions about the subjects are needed but there are no many researches investigating students' misconceptions about the subjects. For these reasons, it is thought that this study will be useful for following researches and it is important.

The aim of this study was to determine the physics education students' misconceptions and the reason of these misconceptions about the transmission and reflection in another medium's boundary. We hope and believe that this research would be useful also for the high school teachers since this is a subject taught in high school level in our country, Türkiye.

II. METHOD

A. The sample

The subjects of this study are a total of 147 students from the 1st, 2nd, 3rd, 4th, and 5th grade students attending Dokuz Eylül University, Education Faculty of Buca, Physics Education Department, Türkiye.

B. The prepared test

In this study, case study research method which is used in the qualitative research methodology had been used [13]. In order to gather information (drawings and ideas of the students) about the subjects, a test containing four questions with drawings had been developed. Actually the questions can be found in many physics books but, as we said before, there are no many researches investigating students' ideas with using similar questions about the subjects. The authors didn't point out the features like the reflected pulse, the transmitted pulse, the amplitude, the width and the velocity in the questions not to direct answers of the students intentionally. The prepared test was checked by three experts, and the necessary corrections were made. Then, it was tested on two students, and it was decided that the questions were not misunderstood. In the questions, students were asked to draw the required shapes and explain their answers.

In the test applied to students, there were totally four questions appropriate to the aim of the study, two of which were related to reflection on fixed and free ends, and two of which were related to reflection and transmission on another medium boundary. The students were explained that the pulses in the questions were mechanical waves with small amplitudes which were progressing on a homogeneous, smooth, and frictionless medium without dispersion [14].

The test was applied to a total number of 147 students of which 33, 34, 32, 24, and 24 were 1st, 2nd, 3rd, 4th, and 5th grade students, respectively, attending Dokuz Eylül University, Education Faculty of Buca, Physics Education Department, Türkiye. Students' drawings were classified independently by two experts in order to maintain the validity, and the common ideas were collected in subtitles. The analyses made by the two researchers were than compared and common results were concluded.

C. The interview structure

It was tried to deeply understand the students' ideas by interviewing. When the test was applied, the students were asked to write their names on their answer sheet in order to able to select the corresponding students in the subsequent interview, and to be able to interview students whose explanations were not clearly understood; the reason for this was explained to the students. Interviews were conducted with 21 students seen as required to interview with. These students were those whose explanations were not understood clearly by researchers during analysis, and those who had certain common misconceptions as determined by the researchers. The interviews were performed separately in a semi-structured interview format, by developing a common structure by two researchers [13]. During the interviews, the students were asked to give detailed reasons for their answers to the questions and these were noted.

The students' written answers and oral explanations (in the interviews) to the test questions were used to determine students' ideas and misconceptions about the subject.

The reflection and transmission subjects are mentioned at the vibrations and waves course given in the 4th semester (spring semester of the second year) and general physics course given in the 1st semester (autumn semester of the first year) according to Department of Physics Education Curriculum. The test was applied to the students beginning of the spring semester and therefore the second class students hadn't learned the related subjects in the vibrations and waves course at that time.

III. FINDINGS AND COMMENTS

The answers given by the students were classified as true, empty and alternative ideas; and the numbers and approximate percentages of students who answered the questions were determined and tabulated.

Our first question was related to meeting of a wave propagating on a rope with a sharp block, in other words, reflection of it on the fixed end is given in Figure 1a, and a correct drawing of a student is given in Figure 1b.

Question 1. As shown in Figure 1a, the velocity of a pulse on a rope which is fixed on a wall is 1 cm/s. How will be the shape of the rope at t=8 s? Please draw and explain your answer.

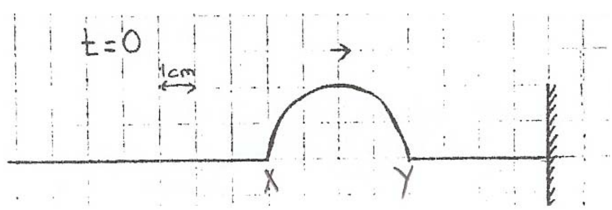

FIGURE 1a. The figure of the Question 1 related to reflection of a mechanical wave on a sharp block.

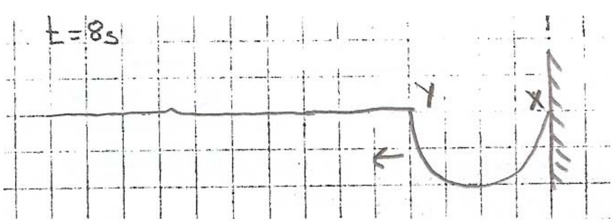

FIGURE 1b. A student's drawing who answered the question correctly.

TABLE I. Number of students and percentages of the answers given to Question 1

The side (up/down) of the reflected pulse	Number of students	Percentage (%)
Upside down (correct)	111	76
Upside up	26	17
Irrelevant response	6	4
No answer	4	3
Total	147	100

There were 93 students who answered this question correctly, and only 4 students who did not answer. In addition to these, there were 18 students who knew that the pulse would be inverted as shown in Figure 2, but displayed it in wrong position.

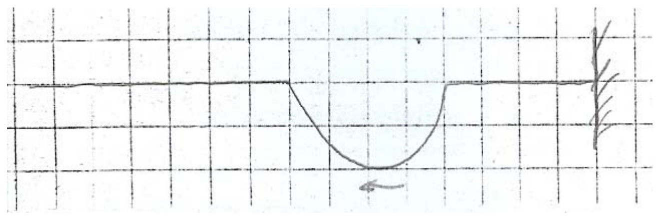

FIGURE 2. An example to the students' answers where the position of the reflected pulse was drawn wrong.

Then, it can be said that 76% of the students knew that the pulse would be inverted when it met a sharp block (Table I). If we consider together the 16 students who reflected the pulse exactly the same, but drew its position correctly, and 10 students who reflected the pulse upside up, and drew its position wrongly; there is a 17 % of student group who thought that a pulse coming to a fixed end would be reflected exactly the same. The interviewed students who had drawings like that supported their drawings with their words also. The drawings of the remaining 6 students could not be classified in a group, and could not be understood why they drew like that.

In the interviews by which it was intended to find why the students drew the position of the pulse wrongly, it was understood that two students had comprehended that the pulse completely inverted at the same time by not taking into consideration the process of being inverted of the wave. It was understood that these two interviewed students did not make any discrimination between the beginning and the end of the pulse, and that they began to count from the end of the pulse. After they had inverted the pulse, they changed the chosen point on the pulse to count. It was also found out that a student who reflected the wave exactly the same in the fixed end, had considered the pulse as a substance, and during the collision, he continued to count by making the end of the pulse as its beginning point.

Our second question was related to meeting of a wave propagating on a rope with a soft block, in other words, reflection of it on free end. A correct drawing of a student is given in Figure 3.b.

Question 2: As shown in Figure 3.a, the velocity of a pulse on a rope connected to a ring which can freely move on a stick is 1 cm/s. How will be the shape of the rope at t=8 s? Please draw and explain your answer.

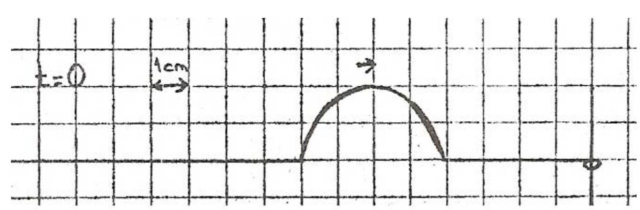

FIGURE 3a. The figure belonging to Question 2 related to reflection of a mechanical wave on a free block.

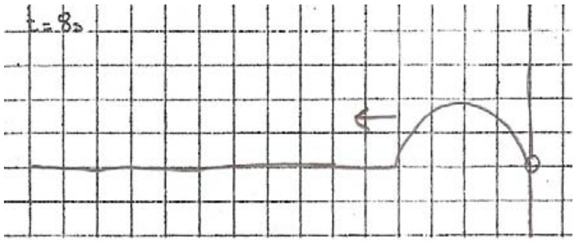

FIGURE 3b. The correct answer of it drawn by a student.

TABLE II. Number of students and percentages of the answers given to Question 2.

The side (up/down) of the reflected pulse	Number of students	Percentage (%)
Upside up (correct)	92	63
Upside down	24	16
Being damped	11	8
Irrelevant response	4	3
No answer	16	11
Total	147	101*

*The sum of the percentages which are not exactly 100 have resulted from the percentages being rounded off.

There were 76 students who answered this question correctly, and 16 students who did not answer (Table II). In addition to these, there were 16 students who knew that the pulse would reflect exactly the same, but displayed it in wrong position. Then, it can be said that 63% of the students knew that the pulse reflecting on free end (or meeting with a soft block) would be reflected upside up. If we consider together the 16 students who reflected the pulse upside down, but drew its position correctly, and 8 students who reflected the pulse upside down, and drew its position wrongly; there is a 16% of student group who thought that a pulse coming to a free end would be reflected upside down. The interviewed students who had drawings like that supported their drawings with their words also. Some of the students also had stated that all pulses meeting a block would get inverted (for this question, it was upside down) regardless of being on fixed or free end.

Another interesting answer given to this question was the idea of the pulse being damped as shown in Figure 4. Translation of the Turkish text in the figure is: "Wave damps".

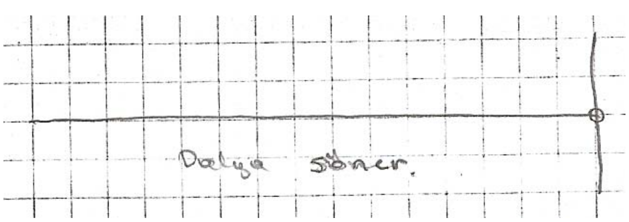

FIGURE 4. An example to the students' answers related to the reflected pulse being damped.

11 students answered in the same manner. Some of the students who wrote explanations beside their drawings had expressed their ideas with these words: "Since the ring is moving, the pulse will disappear, and there will be no return." "The pulse will disperse and dissolve." "Since one of the ends is free, it damps." "The wave does not reflect back." Three of the interviewed students expressed that the pulse would be damped. One of them stated that since the end is free, the incident pulse would provide the end to be swung up and down, and would cause the wave to be damped here, and that there would be no reflection. The drawings of the remaining 4 students were the drawings which could not be classified in a group, and could not be understood why they drew like that. In the interviews intended to find why the students drew the position of the pulse wrongly, the obtained results were the same as the misconceptions mentioned above.

Drawing and the correct answer drawn by a student for Question 3 which aimed to examine the students' misconceptions about the behaviour of a mechanical wave coming to another medium boundary, in other words, its transmission and reflection, where a pulse was propagating from thin rope to thick rope are given in Figure 5a.

Question 3: As shown in Figure 5a, a pulse was formed on a thin rope connected to a thick rope. Please draw the shape of the ropes after the pulse passed from the connection point, and explain your answer.

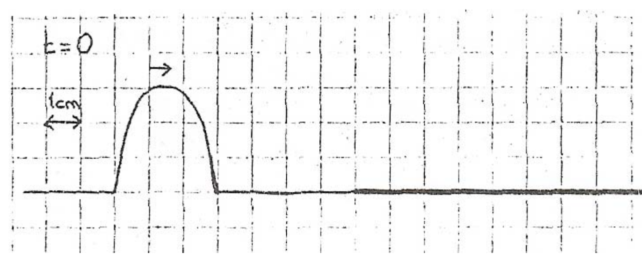

FIGURE 5.a. The figure of Question 3 related to behaviour of a pulse propagating from a thin rope to thick one.

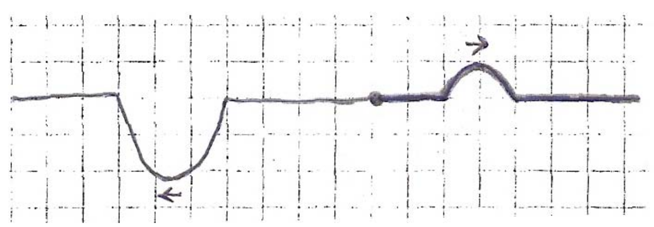

FIGURE 5b. Its correct answer given by a student.

There were only 3 students (2%) who completely answered the question correctly, and 21 students (14%) who did not answer. As a result of the variety of the answers given to the question (56 different figures), it was very difficult to collect the answers under a few titles, so the answers for the transmitted and reflected pulse had been evaluated separately.

TABLE III. Number of students and percentages of the answers given to Question 3 for the reflected pulse

The side (up/down) of the reflected pulse	Number of students	Percentage (%)
Upside down (correct)	64	44
Upside up	27	18
Not being drawn	35	24
No answer	21	14
Total	147	100

27 students reflected the pulse upside up again without inversing it (Figure 6). There were 64 students who correctly inverted the reflected pulse (Table III).

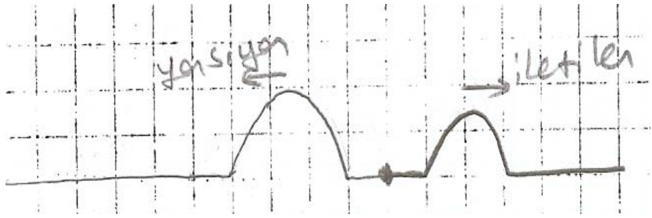

FIGURE 6. An example to the students' answers to Question 3 where the reflected pulse was drawn as upside up.

Another remarkable situation related to the reflected pulse was that 35 students have never drawn a reflected pulse in their drawings (Figure 7). These students seem to have no idea about the fact that some part of the pulse sent from a homogeneous thin rope to a thick one would be reflected, in other words, they seem to be unaware of the reflected pulse.

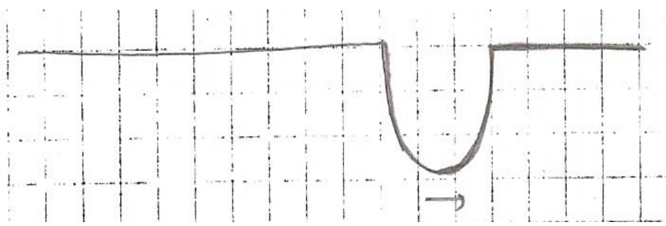

FIGURE 7. An example to the students' answers to Question 3 where no reflected pulse was drawn.

TABLE IV. Number of students and percentages of the answers given to Question 3 for the width of the reflected pulse.

The width of the reflected pulse	Number of students	Percentage (%)
Same (correct)	56	38
Wider than the incident pulse	2	1
Narrower than the incident pulse	33	23
No reflected pulse being drawn	35	24
No answer	21	14
Total	147	100

There were 56 students who expressed in their drawings that the width of the reflected pulse would not change since the medium have not changed (as shown in Figures 5.b, 6, 9, and 10). There were 33 students who drew the width of the reflected pulse smaller than the incident pulse (Figure 8) and 2 students who drew it greater (Table IV).

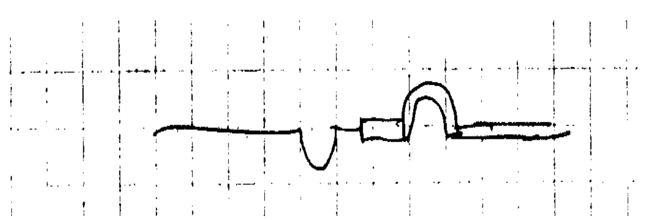

FIGURE 8. An example to the students' answers to Question 3 where the width of the reflected pulse was drawn smaller than the incident pulse.

Because of the students drew their figures roughly in investigating how the amplitudes of the reflected and transmitted pulses was drawn, it was noticed only that the amplitudes of the reflected and transmitted pulses was drawn smaller than the amplitude of the incident pulse, i.e, it wasn't noticed the rule which the sum of the square of the amplitudes of these pulses is equal to the square of the amplitude of the incident pulse.

TABLE V. Number of students and percentages of the answers given to Question 3 for the amplitude of the reflected pulse.

The amplitude of the reflected pulse	Number of students	Percentage (%)
Smaller than the incident pulse (correct)	70	48
Bigger than the incident pulse	2	1
Same	19	13
No reflected pulse being drawn	35	24
No answer	21	14
Total	147	100

Table V shows that 70 students gave the correct answer for the amplitude of the reflected pulse at this question (Figure 6 and 8) . There were 2 students who drew the amplitude of the reflected pulse bigger than the incident pulse and 19 students who drew it as same length as does the incident pulse (Figures 9 and 10).

TABLE VI. Number of students and percentages of the answers given to Question 3 for the transmitted pulse.

The side (up/down) of the transmitted pulse	Number of students	Percentage (%)
Upside up (correct)	109	74
Upside down	9	6
Not being drawn	8	5
No answer	21	14
Total	147	99*

109 students drew the transmitted pulse as upside up as shown in Figures 5.b, 6, 8, and 10; and 9 students drew the transmitted pulse as upside down by reversing it as shown in Figure 7 (TableVI). The written explanations of some of the students, who inverted the transmitted pulse, were as follows: "The thick rope acts as a block, and the pulse becomes inverted." "Since it will pass to the dense medium, it will be reversed." "The thick rope causes the pulse to be reversed as the constant medium." It was observed that 6 students who answered like that did not display the reflected pulse in their drawings (Figure 7). It was obvious that these students had confused the reflected pulse with the transmitted pulse.

There were 8 students who did not draw a transmitted pulse in their drawings (Figure 9). The answers of some of the students who wrote explanations, and who reflected the incident pulse just as the same without changing anything in their drawings, were as follows: "The thick rope acts as a block, and it is inverted." "It acts as a rope fixed onto the wall, and it is inverted."

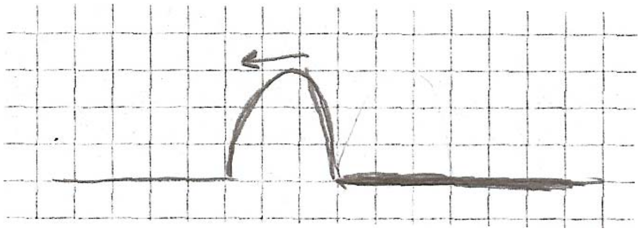

FIGURE 9. An example to the students' answers to Question 3 where no transmitted pulse was drawn.

TABLE VII. Number of students and percentages of the answers given to Question 3 for the width of the transmitted pulse

The width of the transmitted pulse	Number of students	Percentage (%)
Narrower than the incident pulse (correct)	64	44
Wider than the incident pulse	2	1
Same	52	35
No transmitted pulse being drawn	8	5
No answer	21	14
Total	147	99*

In spite of 64 students who displayed in their drawings that the width of the transmitted pulse would decrease as shown in Figures 5b, 6, 8, and 10; 52 students had drawn the width of the transmitted pulse just as the same as the incident pulse without changing anything (Figure 7), and 2 students had increased the width (Table VII).

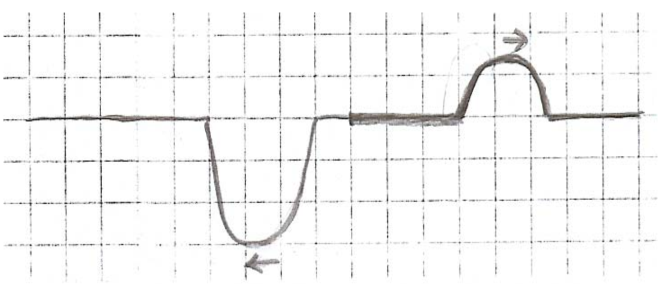

FIGURE 10. An example to the students' answers to Question 3 where the width of the transmitted pulse is smaller than the incident pulse and the amplitude of the reflected pulse was drawn smaller than the incident pulse.

TABLE VIII. Number of students and percentages of the answers given to Question 3 for the amplitude of the transmitted pulse

The amplitude of the transmitted pulse	Number of students	Percentage (%)
Smaller than the incident pulse (correct)	112	76
Bigger than the incident pulse	-	-
Same	6	4
No transmitted pulse being drawn	8	5
No answer	21	14
Total	147	99*

Many of the students gave the correct answer for the amplitude of the transmitted pulse at 3rd question (Table VIII). For this question, 70 students gave the correct answer for the amplitudes of both the reflected and transmitted pulses.

TABLE IX. Number of students and percentages of the answers given to Question 3 for the velocity of the transmitted pulse with respect to the velocity of the reflected pulse

The velocity of the transmitted pulse	Number of students	Percentage (%)
Smaller than the reflected pulse	24	16
Greater than the reflected pulse	15	10
Unchanged	26	18
The reflected pulse or transmitted pulse not being drawn	43	29
Combined	18	12
No answer	21	14
Total	147	100*

As seen in Table IX, there were 24 students who were aware of the fact that the velocity of a pulse passing to a different medium would change and, for this question, that it would decrease (Figure 5b), and 15 students who displayed in their drawings that the velocity would increase (Figures 8 and 10), and 26 students who expressed that the velocity would not change (Figure 6). It could not be understood what some students thought about the velocities of the pulses, since some of them had drawn the reflected and transmitted pulses side by side and some of them had not drawn any reflected or transmitted pulses.

The aim of Question 4 was to examine the students' misconceptions about the behaviour of a mechanical wave coming to another medium boundary, in other words, its transmission and reflection, where a pulse was propagating from thick rope to thin rope. The figure of Question 4 and the correct answer given to this question is shown in Figure 11a and 11b, respectively.

Question 4: As shown in Figure 11.a, a pulse was formed on a thick rope connected to a thin rope. Please draw the shape of the ropes after the pulse had passed from the connection point, and explain your answer.

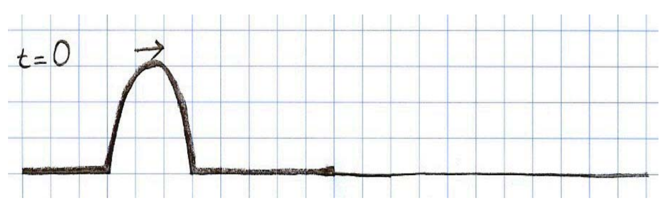

FIGURE 11a. The figure of the Question 4 related to behaviour of a pulse propagating from a thick rope to a thin one.

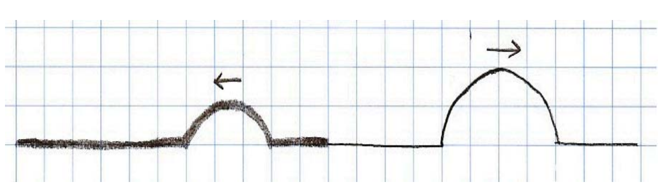

FIGURE 11b. Its correct answer.

The expected written answer of Question 4 was: "The width of the transmitted pulse increases, and amplitude of it decreases. The width of the reflected pulse does not change, and amplitude of it decreases. The transmitted pulse goes faster than the reflected pulse."

There was nobody who completely answered the question correctly, and there were 29 students who did not answer the question at all. As a result of the variety of the answers given to the question, it was very difficult to collect the answers under a few titles, so the answers for the transmitted and reflected pulses were evaluated separately again.

TABLE X. Number of students and percentages of the answers given to Question 4 for the reflected pulse

The side (up/down) of the reflected pulse	Number of students	Percentage (%)
Upside up (correct)	43	29
Upside down	17	12
Not being drawn	58	39
No answer	29	20
Total	147	100

Table X shows that there were 17 students who reflected the pulse upside down by reversing it (Figure 12). 43 students correctly drew the reflected pulse upside up as the incident pulse (Figures 13 and 15).

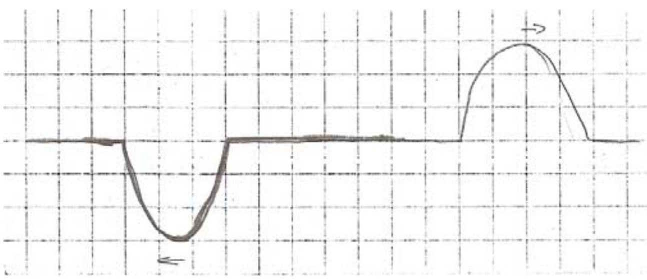

FIGURE 12. An example to the students' answers to Question 4 where the reflected pulse was drawn as upside down.

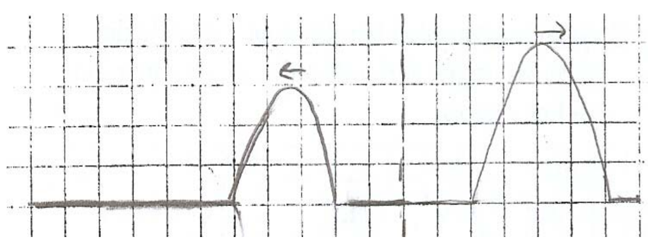

FIGURE 13. An example to the students' answers to Question 4 where the reflected pulse was drawn upside up as the incident pulse.

As in the previous question, in this question, it was observed that there were students who had never drawn the reflected pulse in their drawings (Figures 14 and 16). However; in this question, more students (58 students) never drew the reflected pulse. These students seem to have no idea about the fact that some part of the pulse sent from a homogeneous thick rope to a thin one would be reflected, in other words, they seem to be unaware of the reflected pulse. Some of them had supported their drawings with these words: "It goes on its way in the same direction. There would not be any reflection, because we can not consider the thin rope as a block". "The incident pulse easily passes through the thin rope; there would not be any back reflection".

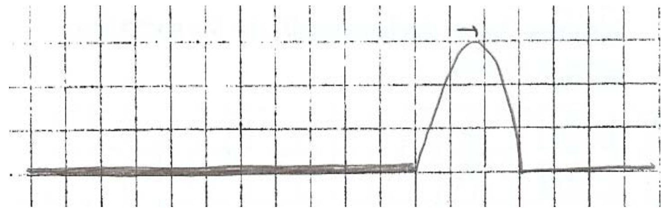

FIGURE 14. An example to the students' answers to Question 4 where no reflected pulse was drawn.

TABLE XI. Number of students and percentages of the answers given to Question 4 for the width of the reflected pulse

The width of the reflected pulse	Number of students	Percentage (%)
Same (correct)	34	23
Wider than the incident pulse	3	2
Narrower than the incident pulse	23	16
Not being drawn	58	39
No answer	29	20
Total	147	100

There are 34 students who expressed in their drawings that the width of the reflected pulse would not be changed since the medium did not change (as in the Figures 12 and 13). There are 23 students who drew the width of the reflected pulse narrower than the incident pulse (Figure 15), and 3 students who drew it wider (Table XI).

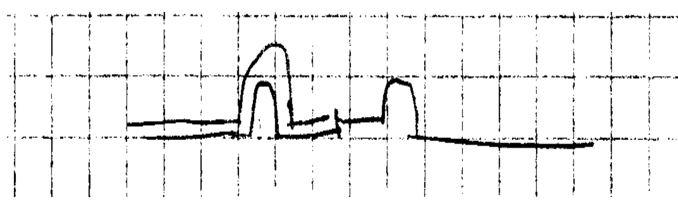

FIGURE 15. An example to the students' answers to Question 4 where the width of the reflected pulse was drawn narrower than the incident pulse.

TABLE XII. Number of students and percentages of the answers given to Question 4 for the amplitude of the reflected pulse

The amplitude of the reflected pulse	Number of students	Percentage (%)
Smaller than the incident pulse (correct)	40	27
Bigger than the incident pulse	1	1
Same	19	13
No reflected pulse being drawn	58	39
No answer	29	20
Total	147	100

Because of the fact that considerable amount of students didn't draw the reflected pulse and some of them didn't answer this question, the correct response rate for the amplitude of the reflected pulse was, unfortunately, 27% (Table XII).

TABLE XIII. Number of students and percentages of the answers given to Question 4 for the transmitted pulse

The side (up/down) of the transmitted pulse	Number of students	Percentage (%)
Upside up (correct)	105	71
Upside down	9	6
Not being drawn	4	3
No answer	29	20
Total	147	100

105 students drew the transmitted pulse as upside up as the incident pulse (Figures 12, 13, 14, and 15); and only 9 students drew the transmitted pulse as upside down by reversing it. There were 4 only students who did not draw a transmitted pulse in their drawings (Table XIII).

TABLE XIV. Number of students and percentages of the answers given to Question 4 for the width of the transmitted pulse

The velocity of the transmitted pulse	Number of students	Percentage (%)
Bigger than the reflected pulse (correct)	11	8
Smaller than the reflected pulse	13	9
Unchanged	16	11
The reflected pulse or transmitted pulse not being drawn	62	42
Combined	16	11
No answer	29	20
Total	147	101*

As seen in Table XIV, in spite of 36 students who displayed in their drawings that the width of the transmitted pulse would increase (Figures 12, 13 and 16); 53 students drew the width of the transmitted pulse just as the same as the incident pulse without changing anything (Figure 14), and 25 students decreased the width (Figure 15).

TABLE XV. Number of students and percentages of the answers given to Question 4 for the amplitude of the transmitted pulse

The amplitude of the transmitted pulse	Number of students	Percentage (%)
Smaller than the incident pulse (correct)	36	24
Bigger than the incident pulse	59	40
Same	19	13
No transmitted pulse being drawn	4	3
No answer	29	20
Total	147	100

About half of the students drew the amplitude of the transmitted pulse bigger than the incident pulse and 36 students gave the correct answer for the amplitude of the transmitted pulse (Table XV).

For the 4th question, some students wrote that the amplitude of the transmitted pulse propagating to thin rope from thick rope is bigger than the incident pulse because of less density of thin rope. This wrong idea may arise from that students are not aware of the reflected pulse. 44 of students who didn't draw the reflected pulse (58 students) drew that the amplitude of the transmitted pulse is bigger than the incident pulse. Maybe, they know that the amplitude of the transmitted pulse propagating to thin rope from thick rope was bigger than the amplitude of the transmitted pulse propagating to thick rope from thin rope and they misused this knowledge for this situation.

For the 4th question, 30 students (% 20) gave the correct answer about the amplitude of the transmitted pulse for both of the reflected and transmitted pulses.

From the wrong answers and some students' explanations given 3rd and 4th questions about the amplitudes of the reflected and transmitted pulses, it is understood that students didn't pay attention conservation of energy.

TABLE XVI. Number of students and percentages of the answers given to Question 4 for the velocity of the transmitted pulse with respect to the velocity of the reflected pulse

The width of the transmitted pulse	Number of students	Percentage (%)
Wider than the incident pulse (correct)	36	25
Narrower than the incident pulse	25	17
Same	53	36
Not being drawn	4	3
No answer	29	20
Total	147	101*

There were 11 students who were aware of the fact that the velocity of a pulse passing to a different medium would change and, it would increase for this question (Table XVI). 13 students indicated in their drawings that the velocity would decrease (Figure 12) and 16 students expressed that the velocity would not change (Figure 13). It was not clear what some students thought about the velocities of the pulses since some of them had drawn the reflected and transmitted pulses side by side or as combined, and some of them had not drawn any reflected or transmitted pulses at all. Because the students who sketched their drawings by considering the velocities of the pulses constituted a small part of the total, it was concluded that the most of the students were unaware that the velocity of a pulse passing to another homogeneous medium would change or maybe they didn't notice it at all. During the interviews, when a student was asked what the energy of the pulse would be, the following statement was obtained: "The velocity of one of them increases, and the other one decreases (the transmitted and reflected pulses are mentioned); thus the energy remains constant". From this explanation, it is understood that some students misused the conservation of energy.

As a result of the interviews done, it was found out that the students had comprehended the amplitude and the width as the same. It was observed that when they expressed that the amplitude would increase, they had increased both the amplitude and the width, and when they said that the amplitude would decrease, they had decreased both of them. And it was understood that an interviewed student had meant the wave having greater width by the "greater wave" expression (Figure 16). Translation of the Turkish text is: "A greater wave is formed."

FIGURE 16. An example to the students' answers to Question 4 where a student drew wider wave for "greater wave" expression.

When asked to another student what he meant by his expression of "greater wave is formed", it was recognized that he did not know what the greater thing would be. When asked to students in the interviews what the amplitude of the pulse was related to, it was understood that some of the students interviewed (8 students) did not know that the amplitude of the pulse was related to its energy. One of the students told that the width of a pulse coming to a thick or a thin rope would not change since nothing was done to change the shape of the pulse. And it was understood that one of the students had tried to draw two pulses having equivalent amplitudes with the incident pulse, by subtracting the amplitudes from each other, since one of the pulses was upside down and the other one was upside up, although she was aware of conservation of energy.

To understand whether or not students' answers change according to class level, all students' answers were marked. As it is known, there are 4 questions in the test. For first and second questions, each has one part but for third and fourth questions, each has seven parts (being upside up/upside down, width and amplitude of the reflected and transmitted pulses, and velocity of the transmitted pulses with respect to velocity of the reflected pulse). Each correct answer for each part was scored one mark and therefore the maximum score of the test was 16.

To understand whether or not students' answers change according to class level statistically, SPSS 11.0 packet program was used. According to one-way ANOVA results (Table XVII), there is meaningful difference between groups. From the results of the Scheffe test (Table XVIII), the differences are between first and third class students in favor of third class students. The average marks of classes are $\overline{X}_1 = 4.88$, $\overline{X}_2 = 5.92$, $\overline{X}_3 = 7.91$, $\overline{X}_4 = 7.58$, $\overline{X}_5 = 6.92$. The test was applied to the students beginning of spring semester and second class students hadn't met the related subjects at the course of vibrations and waves. Therefore, there wasn't any statistical difference between the first and second class students. The third grade students have maximum average mark. This situation probably arise from that the third grade students had learned the related subjects in the course of vibrations and waves at recent time. The decrease of the average marks from third grade level indicates that students forget the related subjects with progressing time.

TABLE XVII. One-way ANOVA results of the test points according to class level

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	193,731	4	48,433	4,187	0,003
Within Groups	1642,636	142	11,568		
Total	1836,367	146			

TABLE XVIII. Scheffe test results according to class level

(I) Class Level	(J) Class Level	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1	2	-1,0330	0,83113	0,818	-3,6271	1,5611
	3	-3,0275*	0,84382	0,015	-5,6612	-0,3938
	4	-2,7045	0,91243	0,072	-5,5524	0,1433
	5	-2,0379	0,91243	0,294	-4,8857	0,8100
2	3	-1,9945	0,83769	0,231	-4,6090	0,6201
	4	-1,6716	0,90677	0,496	-4,5017	1,1586
	5	-1,0049	0,90677	0,873	-3,8351	1,8253
3	4	0,3229	0,91842	0,998	-2,5436	3,1894
	5	0,9896	0,91842	0,884	-1,8769	3,8561
4	5	0,6667	0,98183	0,977	-2,3978	3,7311

Instruction period is five years at the departments of Physics, Chemistry, Mathematics and Biology Education at education faculties in Türkiye. According to the curriculum of education faculties in Türkiye, students have to attend all physics courses in first 3,5 years (7 semester) and then, they have to attend educational lessons in 1,5 years (3 semester) for being graduated. This situation causes for the fifth grade physics education students to forget physics subjects. That the average mark of the fifth grade students is less than the average marks of third and fourth grade students maybe arised from the mentioned reason.

It was also tried to investigate whether or not alternative ideas of the students change according to class level but it was seen that interpretations can not be done according to class level because of irrevelant disturbance of the alternative ideas of the students for each question according to class level.

IV. CONCLUSIONS

It was found out that some of the students had mislearned the reflection principles on fixed and free ends, and that they have more difficulties about the reflection of a wave on free end than the reflection on fixed end. As different from the results obtained in the aforementioned studies, it was observed that some of the students had the idea that all the pulses encountering a block would be inverted, regardless of being on free end or fixed end. As opposed to the result Witmann [6] had obtained in his study, our students did not think that a wave would be damped in the reflection on fixed end; however, similarly, the idea that a pulse would be damped in the reflection on free end was observed among some of the students.

It was observed that the students had some difficulties about the behaviour of a wave coming to another medium boundary. It was seen that some of the students were unaware of the fact that some part of the pulse coming to another medium boundary would be reflected, and some of them were unaware of the transmitted pulse. In both questions (Questions 3 and 4), especially in the question where the pulse was propagating from a thick rope to a thin one, a considerable number of students did not draw a reflected pulse. Some of the students confused the reflected and transmitted pulses with each other. As Ambrose [10] reported in his study, one third of our students drew the transmitted pulse as having the same width with the incident pulse.

In the physics books used in the introductory physics lectures in our university [15, 16] and in physics lessons also, it is stated that the inversion in the reflected wave from the heavier string is similiar to the behaviour of a pulse metting a rigid boundary and that the inversion in the reflected wave from the lighter string is similiar to the behaviour of a pulse metting a soft boundary. Maybe this information misleaded students for the Questions 3 and 4 if they know the reflection principles on fixed and free ends wrongly. Thus, there are 11 students who thought that a pulse coming to a fixed end would be reflected exactly the same and who drew the reflected pulses similarly wrong in both Questions 1 and Questions 3, and there are 6 students who thought that a pulse coming to a free end would be inverted and who drew the reflected pulses similarly wrong in both Questions 2 and Questions 4. Some of the students also thought that all pulses meeting a block would get inverted regardless of being on fixed or free end. This misconception leads them to making mistakes about the behaviour of reflected part of the pulse passing from another medium.

It was revealed that the width and amplitude concepts were not understood by most of the students, or they were confused them with each other; and most of them were unaware that the amplitude was related to energy. More than half of the students did not know that the velocity of a pulse passing to another homogenous medium would change. Also it was observed that they did not pay attention or misapplied for the conservation of energy in their answers. As a result of the interviews made, it was understood that the students thought that the potential energy of the pulses has a direction and this direction would depend on pulses' position (being above or beneath the rope), and the total energy would be calculated regarding these directions. Consequently, these opinions led to making mistakes while drawing the incident and reflected pulses.

The first and second class students have lower average marks, because they hadn't learned the subjects at the course of vibrations and waves when they were asked to reply the test. They also learned the subjects at the high school level, but they probably forget the subjects. Because of the fact that the third grade students had learned the related subjects in the course of vibrations and waves at recent time, they have maximum average mark. From the average marks of the classes, it is understood that students forget the related subjects with progressing time from the third grade.

It was seen that the average mark of the fifth grade students is less than the average marks of the third and fourth grade students. This may probably arised from that the fifth grade physics students didn't take physics lessons in the last three semesters. According to the curriculum of education faculties in Türkiye, physics students have to attend only educational lessons in last 3 semesters. This situation weakens the connection between physics students and physics subjects.

The fact that the average mark of the students is approximately 6,5 is a considerable and an engrossing result. In Palmer's study [12], which identify students' alternative conceptions and scientifically acceptable conceptions about gravity, he stated that answers of 11% and 29% of the grade 6 and grade 10 students respectively were scientifically acceptable. Physics education researchers have documented that, even after studying physics, student performance revealed that they have a weak understanding of fundamental concepts [17].

These results indicated that the students had inadequate information and serious misconceptions about the subject. The authors think that this situation arises from the insufficiency of the preliminary education in the fundamental level, that the subjects are seen simple at the university level, that students are seen already knew the subject at the university level, and that students could not realize their misconceptions about the subject in the higher levels. For this reason, it is crucial to determine these misconceptions and to provide students an ambiance where they could realize their misconceptions during the education and find the opportunity to correct them.

It is strongly recommended that similar studies should be carried out in high school and university levels with different groups of students, that curriculums should be developed intended to eliminate these misconceptions, and that the high school teachers also should consider these misconceptions since these subjects are being taught in high school level for the first time.

The authors didn't point out the features like the reflected pulse, the transmitted pulse, the amplitude, the width and the velocity in the questions intentionally. Because the authors didn't want to direct answers of the students. That many of the students didn't draw the reflected or transmitted pulses affirms this idea. Nevertheless, the fact that the students didn't draw the figures showing the amplitude, the width, the velocity, the reflected and transmitted pulses especially in Questions 3 and 4 doesn't mean that they didn't know exactly. For example, despite knowing that the velocity of a pulse passing from another medium would change, students maybe overlooked to show this in their drawings or to explain in their statements. Also it has been observed that, although it was rare, there were students whose explanations were correct although their drawings were wrong. Therefore, the authors also recommend that different methods should be used together to obtain the students' understanding while studies are being intended to determine the misconceptions.

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