TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 6, Sayı 1, Nisan 2009

Journal of
TURKISH SCIENCE EDUCATION
Volume 6, Issue 1, April 2009

http://www.tused.org

Students' Difficulties about the Wave Pulses Propagating On a Rope

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Received: 15.11.2007 **Revised:** 17.12.2008 **Accepted:** 13.01.2009

The original language of article is English (v.6, n.1, April 2009, pp.50-59)

ABSTRACT

The aim of this research is to determine the ideas of Turkish prospective physics teachers about the factors influencing the velocity of a wave propagating on a non-distributed and homogeneous rope. The sample of the study is 147 prospective physics teachers attending at a state university in Turkey. The answers to an open-ended question and three multiple - choice questions relating to the subject, and the interview notes constitute the data of this study. A qualitative discussion of the data revealed that prospective physics teachers haven't really understood what a wave is. Because of the fact that students don't think waves differ from matter, they can't improve a proper physical model to explain the wave propagation. Students' different ideas using to explain wave propagation are identified and described in this research. Finally, some implications were discussed to improve instruction.

Keywords: Physics Education; Mechanical Wave; Wave Velocity; Students' Difficulties.

INTRODUCTION

Waves are fundamental properties of natural world and understanding of the wave nature has proven to produce many useful tools. In the course of the investigating of the waves' behaviour at the basic level, it is supposed that waves propagate in a homogenous medium however, in many contexts in the laboratory and nature the situation is more complex (Robinson, 2000). But, it goes without saying that students must first have a correct understanding of the fundamental concepts of any subject to understand the further concepts at the more advanced level. For this reason, it is very important what students think about the behaviours of waves propagating in a homogeneous medium and how students infer this situation during the instruction.

In physics education research, students' understanding of topics in introductory mechanics has been thoroughly studied over the last 25 years (Mihas & Gemousakakis, 2007). Wave propagating on a homogeneous rope is one of the important topics in introductory physics, as well, but we didn't encounter many researches about the topic. Nevertheless, a few important researches (Witmann, 2002; Wittmann, 1998; Witmann, Steinberg, & Redish 1999; Şengören, Tanel, & Kavcar, 2006; Tanel, Şengören & Kavcar, 2008) done on the wave subject have showed that students have different ideas about the wave propagating in a homogeneous medium. It is obvious that many of these ideas will not cover correct knowledge essential for the learning of concepts at the upper levels. The topic of mechanical waves is frequently encountered with its applications in many physics topics at the upper level especially in quantum physics, physical and geometrical optics. For being understood some concepts such as interference, reflection, transmission, refraction and phase difference related to the topics at issue, students must first have a correct understanding of fundamental wave properties such as wavelength, amplitude, wave velocity, fundamental wave equation, wave energy, and wave superposition. Once students learn these basic concepts, upper concepts related to these concepts become easier to understand (Qiaovu, 2002).

Learning is a mental process (Özden, 1999) and the prior knowledge of students plays an important role at the learning process. When students meet a new learning environment, they get meanings based on their prior knowledge (Açıkgöz, 2002). To be able to teach a new knowledge successfully, instructor has to investigate the prior knowledge of the students those either support or contradict to it. Some of the prior knowledge may not be consistent with accepted scientific realities. These unscientific ideas are generally called as "misconceptions", "alternative conceptions", or "preconceptions". However, in this article, "students' difficulties" will be used to indicate all beliefs students have about this subject.

Especially, if the students' difficulties concerning with any subjects are ignored, this situation prevents the subjects to be learnt at the upper level. Students have different ideas about the waves propagating on a homogeneous rope, like other many topics of introductory physics. According to the results of the researches (such as Witmann, 2002; Witmann, 1998; Witmann, Steinberg, & Redish, 1999), it has been determined some students' difficulties related to propagating of mechanical waves as follows;

1. Medium is only a transporter of wave, it is directly not deal with propagating of wave.
2. Pulses with different sizes will move with different speeds in the same medium.
3. Greater force applying for the motion of hand creates a greater speed.
4. Students consider waves as objects, rather than a description of waves as a propagating disturbance within a system.
5. Propagation of a wave depends on the creation of wave, not depends on medium properties of the system.

These difficulties are also supported with the outcomes obtained from the answers of teacher candidates educated in the physics education department of our university which they replied either at discussions during the lectures or at examinations.

The aim of this research is to introduce the conceptual and reasoning difficulties of the students about the propagating of a wave pulse in introductory physics at the university level. The research question of this study is what the ideas of the physics student teachers about the factors influencing the velocity of a wave pulse propagating on a non-dispersive and homogeneous rope are.

A wave phenomenon is included in many areas of experimental and theoretical physics at the upper level physics classes. Student difficulties about the fundamental wave behaviour prevents student learning of more advanced concepts. Because of this, the literature in relation to students' understanding of the nature of waves at the introductory physics must be more extensive.

Results of this research can reveal some of these difficulties and can lead to the development of more effective instructional materials on this topic. In most countries this subject is included in the secondary education; therefore the results of this research can be used at this level, as well.

METHODOLOGY

a) Sample

The sample of the study consists of prospective physics teachers attending at a state university in Turkey. A total of 147 students from the 1st, 2nd, 3rd, 4th and 5th grade classes participated in the study. The students had taken the course related to the subject mentioned above in the final semester at high school. In addition, the velocity of waves is mentioned during the general physics course given in the first semester, and the vibration and wave's course are given in the 4th semester according to curriculum of the Department of Physics Education in the Faculty of Education.

b) Research Design

In this study, we used the case study research method applying in the qualitative studies (Ekiz, 2003). Case studies are designed to bring out the details from the viewpoint of the participants by using multiple sources of data (Tellis, 1997). From those ideas that writing and oral test supply different superiority to analyze and describe misconceptions and that products taken from both tests raise the value of results (Schmidt, 1997), data is obtained from both writing test to reach more sample and interviews to get detailed data.

c) Instrument

The answers to an open-ended question and three multiple-choice questions relating to the subject, and the interview notes constitute the data of this study. The multiple-choice questions, which were aimed to measure students' knowledge about how the medium effects the wave velocity were created by the researchers. The open-ended question was inspired by Witmann et al.'s (1999) study, which was related to the factors influencing the velocity of wave propagating on a homogenous rope. Checking the same issue in different settings enhanced both the validity and the reliability of the results (Galili & Hazan, 2000). The students were explained that the pulses in the questions were mechanical waves with small amplitudes which were progressing in a homogeneous, smooth, and frictionless medium without dispersion (Crawford, 1996). The content validity of the questions and their relevance to our goals were checked by three experts.

d) Procedure and Data Analysis

The questions were applied to a total number of 147 students, and then interviews were conducted with 21 students seen as required to interview with. The last group of students is the ones whose explanations were not understood clearly by the researchers during analysis, and the ones who had certain common misconceptions. The interviews were performed separately in a semi-structured interview format (Ekiz, 2003), by developing a common structure by two researchers. During the interviews, the students were encouraged to give detailed reasons to support their written answers. Students' answers were classified independently by the two experts in order to maintain the validity. The analyses made by the same two researchers were then compared and common results were concluded. The level of agreement between researchers was found to be 0,86. The common ideas for open-ended question were grouped in subtitles. Replies to the all questions were given in frequency tables.

Students' knowledge is not evaluated merely as "correct" or "incorrect," but also students' answers are analysed in terms of different reasoning related to the subject and grouped as students' difficulties.

FINDINGS

In this section, frequency tables of answers given by the students to the open-ended and multiple-choice questions and the interview data were evaluated, and then presented. It was said to students that the pulses in the questions are homogeneous and mechanical waves with small amplitude that do not disturb through a uniform environment.

The open-ended question is given in Figure 1 and the groups of the students' responses are given in Table 1 and the frequency distribution of these groups is given in Table 2.

Two long, homogeneous taut strings are attached to a wall as seen in the sketch. Two persons move their hands and create two pulses with small amplitudes on the strings at the same time and same distance to the wall. Although the pulses were created at the same time, they reached the wall at different times. How do you explain the reasons of the difference between the velocities of the pulses? Please list all of the probabilities.

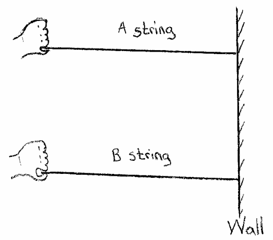

Figure 1. *Open - ended question*

Table 1. *Groups of students' responses for the open – ended question in Figure 1.*

Groups	Students' Responses *(The reason of the difference between the velocities of the pulses is that the.....................is different.)*
A	Amplitude of the pulses /Intensity of the pulses / Energy of the pulses / Height of hand
B	Mass density of the strings/ Thickness of the strings
C	Tension of the strings
D	Frequency of the pulses / Velocity of shaking hand
E	Width of the pulses / Wavelength of the pulses

At the second column of the table, the students' alternative answers were given. Since these answers are the students' self expressions, the expressions that have the same meanings and used instead of other meanings were categorized in the same group. Width and wavelength terms were put under the same category, since it has been seen that students are using these terms for each other and trying to define the same things. Nevertheless, since students are generally using wavelength instead of pulse's width, the expression will be given in students' explanations without any correction.

Table 2. *Percentages of the groups for the open – ended question in Figure 1.*

Groups	%
A	8,2 (N=12)
C	2,0 (N=3)
E	4,8 (N=7)
B + C	25,8 (N=38)
D + E	22,4 (N=33)
B+C+D	3,4 (N=5)
A+B+C	14,2 (N=21)
A+B+C+D+E	19,0 (N=28)

As it was presented on the table above, several answers of the students have come across relating the speed change of an undisturbed wave with small amplitude moving along a string. There are 26 % students who say that the speed only depends on string mass density and tension. The students have added other variables to their knowledge even they know that mass density and tension do affect the speed (See Table 2).

Despite the students using mass density (μ) and tension (F) to explain these variables' effects on the speed correctly with $v = \sqrt{F/\mu}$, interviews with students who only wrote mass density and tension, but did not explain their effects on the change of speed as their answers, revealed their thoughts that an increase in tension would decrease the speed. While explaining this situation, one of the students has used the explanation; "in stiff string, amplitude, and therefore speed would be small", and another one; "when tension of string increases, resistance increases too, therefore speed decreases". One student, on the other hand, in his written answer explained the mass density effect on the speed as "…increase in mass density of a pulse means an increase in its mass and this reduces the speed. So, objects with big mass need more energy to move." It is seen that even though the students know correct elements, they have completely wrong ideas regarding their effects on the speed change. It is also seen that, although the students know the correct answer, they do not know the reason of it. Furthermore, they completely misinterpreted the question and arrived to the conclusion that an increase in tension would decrease the speed.

From the explanations of the students who include frequency or amplitude to mass density and tension, it can be derived that they think that F, from $v = \sqrt{F/\mu}$ formula, is the force affected the pulse by the source. Among these students, the ones who added frequency to their answers considered an increase in the speed due to the increase force while the swinging speed of hand increases, the ones who added amplitude considered that when hand's height increases it would increase the speed due to the increase force. During interview, when the reason has asked to a student, who thought the speed of swinging hand would affect the speed of pulse, he stated that "during high speed motion of hand more force is applied and pulse can travel faster".

These types of answers, as explained in several studies (Witmann, 2002; Wittmann, 1998; Witmann, Steinberg, & Redish 1999), resulted from the students' ideas that pulses like objects and these ideas led them to apply dynamic laws to pulses.

Students who used wavelength / amplitude terms explained wavelength's effect on the speed as $v = \lambda.f$. Equally, the ones who added frequency to their answers used the same equation in order to explain frequency effect on the speed. This situation shows that the students were unable to interpret the relationship between wavelength and frequency correctly. The students stated in their explanations that "when wavelength increases speed increases, and also when frequency increases speed increases."

Students who used the amplitude term in their answers have tried two different methods in order to explain the amplitude effect on speed. The first method is the wave function and the second one is the wave intensity or energy. The students who have misused the wave equation, explained $x = A.\cos wt$ as position of wave, and its derivative to find wave speed, moreover wave speed dependency on amplitude. During interviews, when the meaning of "x" has asked to a student, he implied that "x" is travel along horizontal line. The students who used wave intensity or energy terms in their answers stated that wave density is proportional to square of amplitude and according to $E = (1/2)mv^2$ equation. The speed of an object with constant mass increases when its energy increases. One of the students, during interview, has explained as "wave with big amplitude carries more energy, so reaches to wall quicker", and the other student stated as "if we raise our hand higher we can give more energy to pulse".

These answers are also the evidences for students' ideas to consider pulses as objects. Students identified an object's mechanical energy with energy of a pulse and tried to explain speed of a pulse with kinetic energy and also correlate this situation with amplitude using energy-amplitude relationship, therefore revealed their confusion in their minds.

Figure 2 indicates the multiple-choice questions and Table 3 indicates frequency distribution of answers in the following. These questions were asked as multiple-choice in order to support the first question to reveal students' ideas relating pulse travel. Generally, the students were not be able to correlate the relationship between pulse travel and environment in their answers. In these questions, the effects of environmental changes on pulse's wave speed and amplitude were asked. The questions and frequency distribution of students' answers and interview notes were given below.

As seen in the sketch, a pulse with small amplitude propagates from a string with greater mass density to a string with less mass density. Please answer the questions below.

i. How would be the velocity of the transmitted pulse respect to the velocity of the incident pulse?

a) greater b) smaller c) same

ii. How would be the velocity of the reflected pulse respect to the velocity of the incident pulse?

a) greater b) smaller c) same

iii. How would be the width of the transmitted pulse respect to the width of the incident pulse?

a) greater b) smaller c) same

Figure 2. *Multiple - choice questions.*

Table 3. *Percentages of the students' responses for multiple - choice questions in Figure 2.*

Test Items	Choices			
	Greater %	Smaller %	Same %	No answer %
i	46,2 (N=68)	31,2 (N=46)	13,6 (N=20)	8,8 (N=13)
ii	27,9 (N=41)	39,4 (N=58)	19,0 (N=28)	13,6 (N=20)
iii	36,0 (N=53)	29,9 (N=44)	17,0 (N=25)	17,0 (N=25)

During the interview with two of the students, who signed "same" in three questions, stated that speed of pulse depends on wavelength and frequency, and these two properties are source dependent, and if there is no change in source there would not be any change in frequency and wavelength, therefore, in speed. One of these two students, who thought transmitting pulse speed would be higher, stated that "wavelength of the transmitting pulse on thin string would increase, so its speed", and another student stated that "amplitude on thin string would increase, so its speed".

One of the students, who considered pulse transmission from thicker string to thinner one as a collision, stated that "pulse speed would increase due to conservation of momentum." The same student also stated that the speed would increase according to $M.v = m_1.v_1 + m_2 v_2$ formula, which is used for elastic collisions, due to pulse mass decreases on thinner string. The students, who thought that speed would be smaller, related this with amplitude and energy terms. One student stated that "pulse transmits to thinner string becomes smaller, therefore small pulse travels faster". Another student stated that "the pulse's amplitude on thinner string would increase and travels faster".

During the interview one of the students, who chose reflecting pulse would be bigger, explained his answer as "since this amplitude is higher, speed is higher." The ones who thought speed would be smaller stated that "small amplitude decrease the energy of the pulse", "big mass moves slowly". These explanations are the same as those given of the first questions.

One of the students, who thought the transmitting pulse's amplitude would be bigger, has explained his idea as "it will pass to thin string, but it also increases". One of the students, who thought the transmitting pulse's amplitude would be smaller, has explained his idea as "not all of them could pass to the thinner string". This student also considered the wave to decrease in both amplitude and width.

Students' answers to the multiple-choice questions and interview statements support their mistakes in answers of the first question. Also, they accepted a pulse as an object and used mechanic laws in their statements, misinterpreted the relationship between speed, amplitude and frequency, and correlate the travel speed and amplitude of pulse. Furthermore, it is obvious that the students have not applied the principle of conservation of energy to the pulses.

CONCLUSIONS, DISCUSSION and SUGGESTIONS

The results of this current study indicate that physics education students have some difficulties about the velocity of mechanical waves with small amplitudes which were propagating in a homogeneous and smooth medium without dispersion

The students' difficulties which were found by interpreting the research data are listed below:

1. In the equation of $v = \sqrt{F / \mu}$, F is a force affected the pulse by the source.
2. The mediums that have more tension slow down the pulses.

3. According to the equation of $v = \lambda . f$, the velocity depends on wavelength and frequency.
4. The pulse which has bigger amplitude requires bigger force and this event increases the velocity.
5. The waves with bigger amplitude move fast because of having more energy.
6. Waves move fast on the systems having low mass density because of having low mass.
7. The differentiation of the equation of $x = A.\cos wt$ gives the velocity of the pulse which propagates.
8. The medium doesn't affect the velocity of the pulse but the shape of the pulse affects it.
9. Both the amplitude and the width of a pulse transmitting to another medium decrease/increase always together.

These results show that the students have some conceptual difficulties in understanding what a wave is. The students were far away describing waves as a distribution of the complexity in a system. They couldn't improve a proper physical model to explain the wave propagation. They tried to explain the wave propagation by using the concept of propagation of matter. As stated in several studies (like Witmann, 2002; Wittmann, 1998; Witmann, Steinberg, & Redish 1999), it appears that the students generally thought pulses as substance. Therefore, they try to use laws of the motion and they interrelate the velocity of a pulse with formation of the pulse rather than property of the medium itself. In addition, it appears that they misuse the equations on waves and they misinterpret them. The students thought that the medium was the pulse itself and the medium was the thing moving. They didn't think that the medium carries the energy of the pulse from one point to another point. The facts that mechanical waves need a medium to propagate and the medium is not a mechanical wave itself must be taught conceptually to students.

From the results, it appears that the velocity of propagating direction cannot be distinguished from the velocity of vibration direction. For this reason it appears that many variables in wave equations cannot be understood meaningfully. For example some students used wave equation's ($x = A.\cos wt$) derivative to find speed of propagation. Pointing out the difference between these velocities put away some misunderstandings easily. This situation is an important detail which must not be ignored.

The results presented above show that the students have serious misconceptions about the subject. It is a fact that this situation results from deficiency of teaching the subject at introductory level and that students were unaware of their misconceptions on the subjects at further levels. For instance, the mechanical momentum that is carried by waves in linear theory of the wave equation has been neglected in textbooks and in the pedagogical literature (Gauthier & Rochon, 2004; Gauthier, 2003). For this reason, students have attempted to explain change of wave's speed by theory of conservation of momentum for elastic collisions.

That students are given the equation of $v = \sqrt{F / \mu}$ related the subject and only quantitative problem solutions are used generally, doesn't provide that students understand the nature of waves better. Various activities that were indicated in the study conducted by Bellomonte, Fazio, Sperandeo-Mineo, and Tarantino, (2004), emphasizing that the propagation of waves in different medium is deeply affected by the nature of medium that may help students to understand nature of waves.

"F" is used to state the term "force" and "T" is used to state the term "tension in a medium" in physics. Because of this, when the equation of $v = \sqrt{F / \mu}$ for the velocity of a wave propagating in a homogeneous and smooth mediums is used, the tension in a medium should be shown with “T” rather than “F”. We think that this usage is more appropriate meaningfully and it prevents students’ difficulties due to wrong usage.

The students’ answers to the open-ended question obtained from the literature and multiple-choices questions allowed different misconceptions to be uncovered. They also supported the same common misconceptions obtained before. This situation verified the idea that different samples are likely to lead to different results. It is 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. Secondary school teachers also should consider these misconceptions since these subjects are being taught in secondary school level for the first time. The probable reason for the existence of these misconceptions even at university years is that these subjects are not dwelt upon because of assuming to be known by every student at university.

The fact that even in the final grade prospective physics teachers still have the same misconceptions shows that correction of misunderstanding on pre-knowledge is very difficult. Classroom environments where students recognize their alternative ideas and have opportunities to correct them with detailed debates and various activities must be provided during the teaching of this subject.

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TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 6, Sayı 1, Nisan 2009

Journal of
TURKISH SCIENCE EDUCATION
Volume 6, Issue 1, April 2009

http://www.tused.org

Prospective Biology and Chemistry Teachers' Satisfaction with Laboratory and Laboratory Facilities: The Effect of Gender and University

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Received: 15.05.2008 **Revised:** 16.12.2008 **Accepted:** 15.02.2009

The original language of article is English (v.6, n.1, April 2009, pp.60-71)

ABSTRACT

The purpose of the study was to investigate last year prospective biology and chemistry teachers' satisfaction level with laboratory and laboratory facilities offered by their department and faculty with regard to gender and university. 60 senior prospective Biology Teachers and 101 senior prospective Chemistry Teachers participated in the study. Prospective Science Teacher Satisfaction Scale (PSTSS) was used for obtaining relevant data. PSTSS consists of five sub-scales. For this study, we used "laboratory and its facilities" subscale consisting of 14 items. The alpha (α) level of this subscale was .93. The results pointed out that last year prospective Biology and Chemistry Teachers had a tendency towards satisfaction on biology and chemistry laboratories but not at the desired level. Significant difference was not observed between male and female participants. Most of variance of dependent variable was accounted by the effect of school (university) which suggests that school facilities greatly influence student satisfaction.

Keywords: Satisfaction; Laboratory and Laboratory Facilities; Prospective Biology and Chemistry Teachers.

INTRODUCTION

Over the past 10 years, a substantial number of studies have examined the impacts of college on students' motivation, success and satisfaction. Many of these aimed at exploring the relationships between students' college experiences and learning, development, and satisfaction. Some of those revealed that colleges and universities had a great role for shaping students' overall satisfaction (e.g. Wiers-Jenssen, Stensaker & Grogaards, 2002). Further, some others investigated the impact of academic department on students' motivation and success (Cameron & Ettington, 1988; Hartnett & Centra, 1977). Similarly, it was found that academic departments had a significant impact on student satisfaction and student performance (Elliott & Shin, 2002). Umbach and Porter (2002) examined the effects of different departments and their characteristics on students' satisfaction. They found that department characteristics significantly contributed to