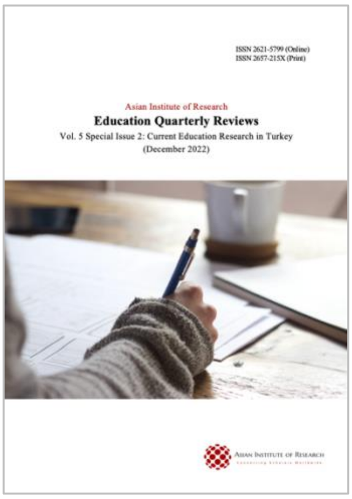


Education Quarterly Reviews

Çalış, S., & Ergül, N. R. (2022). Case Study on Science Teacher Candidates' Understanding of the Wave Concept. *Education Quarterly Reviews*, Vol.5 Special Issue 2: Current Education Research in Turkey, 361-372.

ISSN 2621-5799

DOI: 10.31014/aior.1993.05.04.629

The online version of this article can be found at:
https://www.asianinstituteofresearch.org/

Published by:
The Asian Institute of Research

The Asian Institute of Research *Education Quarterly Reviews* is a peer-reviewed International Journal. The journal covers scholarly articles in the fields of education, linguistics, literature, educational theory, research, and methodologies, curriculum, elementary and secondary education, higher education, foreign language education, teaching and learning, teacher education, education of special groups, and other fields of study related to education. As the journal is Open Access, it ensures high visibility and the increase of citations for all research articles published. The *Education Quarterly Reviews* aims to facilitate scholarly work on recent theoretical and practical aspects of education.

Asian Institute of Research
Connecting Scholars Worldwide

The Asian Institute of Research
Education Quarterly Reviews
Vol.5 Special Issue 2: Current Education Research in Turkey, 2022: 361-372
ISSN 2621-5799

DOI: 10.31014/aior.1993.05.04.629

Case Study on Science Teacher Candidates' Understanding of the Wave Concept

Sevgül Çalış[1], Nimet Remziye Ergül[2]

[1,2] Bursa Uludağ University, Turkey

Correspondence: Sevgül Çalış. E-mail: scalis@uludag.edu.tr

Abstract
This study aimed to determine science teacher candidates' understanding of the wave concept under the headings of the essential characteristics of waves and their place and importance in daily life. The research was carried out with 53 science teacher candidates studying in the first grade in the education faculty of a state university in Turkey in the 2021-2022 academic year. The research used a criterion sampling method to determine teacher candidates. It also employed the case study method, one of the qualitative research methods. To determine the opinions of teacher candidates on the wave concept, researchers developed data collection tools containing ten open-ended questions. The questions in the form, a data collection tool in this study, were prepared to include conceptual, transactional, and relational categories. Three questions were conceptual, four were transactional, and three were relational. Evaluating the study's findings in general terms, we can conclude that the candidates knew the concepts related to the wave. Still, they were not successful in explaining the wave concept, classifying them according to physical characteristics, and indicating the characteristics of wave types.

Keywords: Wave Concept, Conceptual Understanding, Science Teacher Candidates

1. Introduction

Although concept teaching is one of the crucial goals in science teaching, many studies reveal that many students fail to understand basic scientific concepts in depth. Understanding and developing students' conceptual understanding has been a fundamental goal in science education in recent years (Nieminen et al., 2012). However, many students often fail to understand science concepts in depth, making it difficult for students to apply what they have learned.

One of the critical problems encountered in concept teaching is students' misconceptions. Misconceptions can be interpreted as misunderstandings incompatible with the scientific explanation of natural events or phenomena that occur in the real world (Modell et al., 2005). Students' experiences with physical events may lead to incorrectly biased ideas or misconceptions about physical concepts (Neidorf et al., 2020). Misconceptions often have a negative impact on students' science learning in later years because they produce a result that prevents the learning of a scientifically accepted concept. In addition, misconceptions have a cumulative effect on students, ranging from primary education to the point where they have a certain level of expertise (Chen et al., 2019; Potvin & Cyr, 2017).

According to Bao & Koenig (2019), science education aims to develop high-level reasoning skills and promote deep conceptual understanding in the twenty-first century. For this purpose, many models and definitions have been created to examine and define students' conceptual information status and development. As a result of the examination of some studies on modelling, students' information structures have shown that learning depends on the context. It has also been concluded that students with poor conceptual understanding often have information structures associated with isolated conceptual structures that cannot establish similarities and contrasts between contexts (Bao & Koenig, 2019).

Gaining conceptual understanding, thinking, and problem-solving skills are the expected results in 21st-century science learning (Resbiantoro et al., 2022). The OECD Future of Education and Skills 2030 project defines information as " covering facts, concepts, ideas and theories about certain aspects of the world".In the OECD Learning Framework 2030, a product of the same project, four different types of information are mentioned: discipline, interdisciplinary, epistemic and procedural. Interdisciplinary information can help students transfer information from one discipline to another. Thanks to it, students can learn to convey critical concepts or big ideas across different disciplines (Harlen, 2010). However, when students do not understand the concept, their ability to apply it to a new situation or discipline decreases considerably. Key concepts or big ideas are included in every subject, but they can be recognized as "meta-concepts" or "macro-concepts" on different subjects (Erickson et al., 2017). According to Day & Goldstone (2012), students should recognize structural or conceptual similarities to transfer their previous information to the new situation. However, studies on this subject show that students are unsuccessful (OECD Future of Education and Skills 2030 project).

As a result of the integration of twenty-first-century skills into the Physics Education Research (PER) literature, a broadly defined set of education and research goals has been proposed for future PER studies. One of these proposals is discipline-specific deep learning. Also, some popular frameworks are conceptual understanding, problem-solving, information structure, deep learning and information integration. The other is discipline-based ideas, intersecting concepts and practices. What is meant by intersecting concepts here is to develop transferable scientific reasoning skills (Bao & Koenig, 2019).

The wave concept and Its Significance

The wave concept is one of the essential and basic concepts of science. Because it includes a wide range of physics subjects such as acoustics, optics, quantum mechanics and electromagnetic waves, in other words, this comprehensive field within physics contributes to a better understanding of physics (Aykutlu et al., 2022). Understanding vibration and wave concepts, as in other physics subjects, requires not only students' basic understanding of information but also complex thinking to understand the characteristics and types of waves (Furqani et al., 2018). In this respect, an in-depth understanding of mechanical waves is crucial (Xie et al., 2021). Teaching about wave structure and function is a critical element of science programs, and Next Generation Science Standards (NGSS) are supported by Applications in Waves and Information Transfer Technologies. To support students in learning these ideas, teachers often aim to develop wave chart models that define different aspects of students' wave structure (Enderle et al., 2021).

According to Xie et al. (2021), the propagation of a mechanical wave is the collective movement of a multiparticle system defined as the environment, which is new to most students and difficult to conceptualize. In teaching wave behaviour, many new concepts, such as speed and energy, go beyond particle-based identification, such as wavelength, period, frequency, and amplitude, and are used to describe particle-like objects. As a result, it can be difficult for students to understand the nature of waves and their difference from particle-like objects.

Today, interdisciplinary concept teaching or concept-based teaching is gaining importance. The wave concept is a concept that has an interdisciplinary characteristic, and we frequently encounter it in our daily life. On the other hand, the research revealed many deficiencies related to understanding the wave concept and its essential characteristics at all levels. Wiyantara et al. (2021) conducted descriptive research to determine the perceptions and representation levels of secondary school students regarding wave concepts. The results of the research show that there are many students with a deficiency of information and misconceptions. Tumanggor et al. (2020), in their research with 35 physics education students and aimed to determine the misconceptions of teacher candidates about mechanical waves, stated that the biggest misconception they detected was about the general characteristics such as waves represented by the graph and wave frequency, wave source and environment. According to the results of the Mechanical Waves Conceptual Survey (MWCS), designed to evaluate the level of understanding of four main subjects such as propagation, superposition, reflection, and standing waves, Barniol & Zavala (2016) conducted a study with 541 university students. They concluded that students had more difficulty in propagation and standing waves and especially in the subtitle of sound. They had less difficulty in superposition and reflection. Taşlıdere (2021) investigated the individual and relative effectiveness of two conceptual change practices on the conceptual understanding of science teacher candidates and their misconceptions of mechanical waves. He consequently showed that conceptual change texts enriched with concept cartoons might be more effective in increasing students' conceptual understanding levels and reducing misconceptions about mechanical waves. In their study with 13 teacher candidates, Aykutlu et al. (2021) aimed to determine the candidates' conceptual understanding regarding the standing wave concept. As a result of the research, it was determined that there were problems in teacher candidates' conceptual understanding of the standing wave concept and that they also had incomplete information and unscientific opinions. Gülçiçek et al. (2018) designed three experiments and experimental instructions to determine the effect of different laboratory approaches on the understanding of wave concepts of physics teacher candidates. When they evaluated the pre-test and post-test results and the interview results with students after the applications, they stated that their applications did not yield convincing results. Küçüközer (2010), in his study with science teachers candidates, aimed to describe the conceptual understandings of teacher candidates about the primary events and concepts of wave physics, the creation, spread and initiative of mechanical waves, and to identify misconceptions. The study determined that teacher candidates had misconceptions about mechanical waves' basic phenomena and concepts.

The wave concept and related subjects are given in detail in the 10th and 11th grades in the high school program in Turkey. The wave concept is critical because it has an interdisciplinary character and is a concept we frequently encounter daily. Research on the subject reveals the existence of many deficiencies related to understanding the wave concept and its essential characteristics in each level of students since it is impossible to go further without understanding the wave concept and its characteristics. Most studies have focused on mechanical waves, such as the propagation of waves, standing waves, sound, water and spring waves. This study, unlike others, aimed to understand what the wave concept is, to know the essential characteristics of waves and to determine the understanding of the wave concept in our lives and its importance.

The research problem in line with the purpose is "What are the understandings of science teacher candidates about the wave concept?".

Sub-problems are as follows:

1. What is the level of science teacher candidates' understanding of the wave concept?
2. What is the level of science teacher candidates' understanding of general wave concepts?
3. What is the level of science teacher candidates' understanding of wave types?
4. What is the level of science teacher candidates' understanding of the importance of waves?

2. Method

The research employed the case study method, one of the qualitative research methods. Case studies focus on the selected situation or problem to examine the subject investigated in detail (Creswell, 2014).

2.1 Participants

The research was conducted with 53 science teacher candidates studying in the Science Teaching Department of the Faculty of Education of a state university in Turkey in the 2021-2022 academic year. Forty-one of the candidates who participated in the research were females, and 12 were males. The research used a criterion sampling method to determine teacher candidates. For this purpose, the fact that teacher candidates took the Physics course in the 10th and 11th grades of high school was determined as a criterion.

2.2 Instruments and Procedures

A data collection tool was developed based on high school physics course achievements, relevant literature review and expert opinions To determine the teacher candidates' understanding of the wave concept. Moreover, a pilot application was conducted with three teacher candidates who had taken the Physics I course in the science teaching program to determine the intelligibility of the questions. The developed data collection tool contained 10 questions about the waves unit taught in the course. The questions were prepared to include conceptual, transactional, and relational categories (Durukan, 2019). Questions 1 to 3 in the data collection form were conceptual, 4, 5, 6 and 7 were operational, and 8, 9 and 10 were relational. Data collection forms were given to teacher candidates during the course, and they were expected to answer within two lesson hours. The questions given to teacher candidates through data collection forms are shown below:

1- What is a vibration movement? Give an example of a vibration movement.
2- Explain the wave concept, and write down all the characteristics you know about the wave concept and the related concepts.
3- What does wave movement mean?
4- Draw a wave image to show all the characteristics you know of the shape.
5- How are waves classified according to their physical characteristics?
6- What are the wave types? Write down the examples you know of these types.
7- Write the characteristics of the wave types and give examples.
8- Explain whether waves matter in our daily lives.
9- Write down the wave examples you may encounter in your daily life.
10- Give examples by specifying the beneficial and harmful characteristics of the waves.

2.3 Data Analysis

Content analysis was applied to the data obtained from the teacher candidates through written forms. Then the codes, categories and themes that emerged from the students' expressions in the written forms were determined separately by two researchers. After this stage, the researchers came together and evaluated the results. The reliability of the findings was determined as 81% consistency using Miles & Huberman's (2002) method, and the states where there was a difference between the researchers were re-evaluated, and the final state was reached. The results were presented in tables by bringing them together within the framework of themes. The volunteer teacher candidates in the study were informed about the purpose of the study and acted under research ethics. The participants were coded as S1, S2... to protect the confidentiality of the candidates.

3. Results

As the first sub-problem in the study, two questions were asked to the science teacher candidates to determine their level of understanding of the wave concept. Within the scope of the first question, they were asked to define the vibration movement and give examples of it. Four main themes emerged from the answers of teacher candidates regarding this question. The most frequently mentioned themes were "periodic oscillation movement around the equilibrium point" with (f=25) and "movement caused by the contact of particles in a material environment" with (f=13). Other themes were listed as (f=6) "movement caused by waves" and (f=3) "movement formed when force is applied". Figure 1 shows the resulting themes.

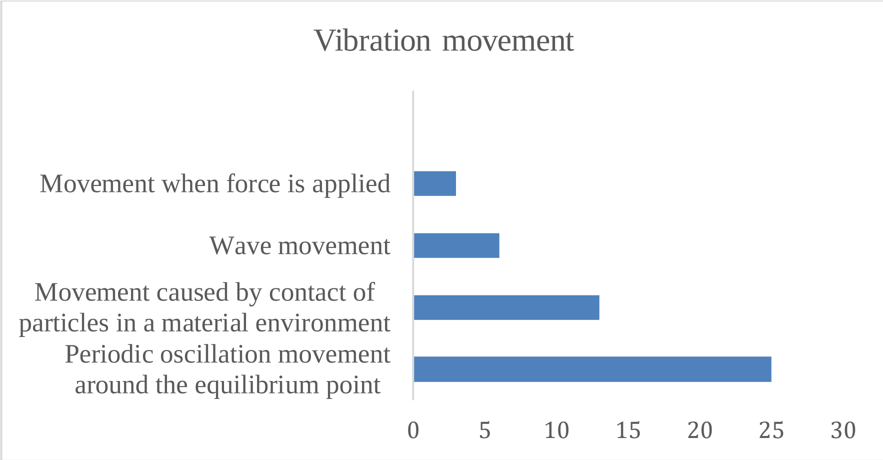


Figure 1: Themes for defining vibration movement

Examples of student statements for the first question are given below.
S11 "It is the event of mobilizing the object with the mechanical effects applied by the atoms that make up a substance. Trembling movement of drums, drums, etc. while playing".
S15 "Vibration is constantly moving between two points in a certain period. For instance: movement of the pendulum of the pendulum clocks".
S20 "It is the movement formed by the union of force with the material environment".
S39 "It is the periodical movement of something. Guitar wire can be given as an example ".

The first part of the second question about the same sub-problem asked for an explanation of the wave concept, and the second part asked about the characteristics of the wave concept were asked in the second part. While 27 teacher candidates could not answer this question, four themes for the wave concept emerged from the answers of 26 teacher candidates. These themes were defined as movement caused by vibration (f=16), movement caused by matter interaction (f=5), periodical movement (f=3), and mechanical deformation (f=2). Regarding the characteristics of the wave concept, ten themes emerged. These themes were defined as period (f=19), frequency (f=19), wavelength (f=18), amplitude (f=15), speed (f=12), peak (f=6), wave pit (f=6), energy(f=1). On the other hand, some students wrote down characteristics unrelated to the wave concept (f=9). Figure 2 and Figure 3 explain the themes obtained.

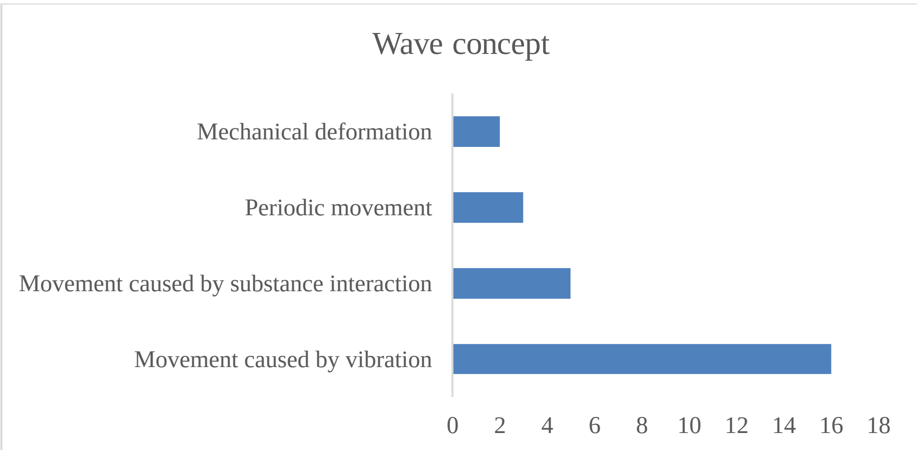


Figure 2: Themes for explaining the wave concept

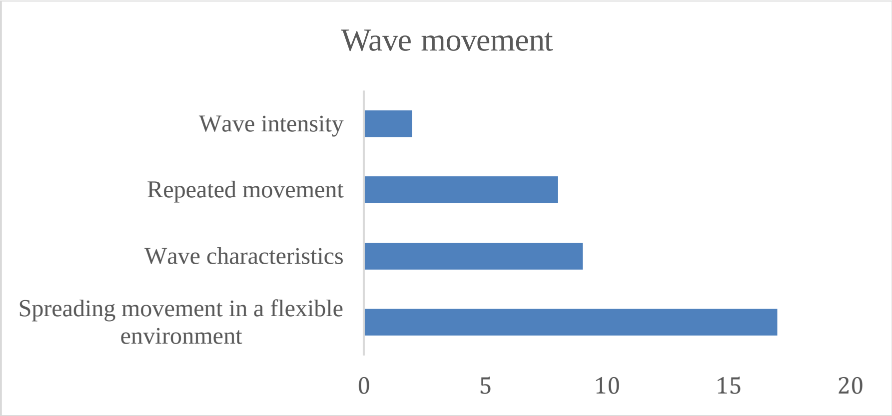


Figure 3: Themes for the characteristics of the wave concept

Examples of teaher candidates' statements regarding the second question are given below.
Examples of explaining the wave concept:
S10 "Wave is the movement that occurs due to vibrations".
S23 "The shape formed in the environment changes while the energy transferred to the environment by the vibration movement is transferred from one place to another".
S25 "It is the spread of the energy generated from the vibration movement from one point to another. Wave is the energy transfer".
S42 "It is the movement of an item collectively due to other factors".
S51 "The wave consists of vibration movements".
Examples of characteristics of the wave concept:
S12 "Wavelength, frequency, period, wave source and environment".
S13 "Wave peak and pit, amplitude, wavelength, source".
Questions 3 and 4 were asked to investigate the level of science teacher candidates' understanding of general wave concepts as the second sub-problem of the study. The third question asked to define the wave movement, and conclusively four themes emerged, which were determined as propagation movement in a flexible environment (f=17), wave characteristics (f= 9), repeated movement (f= 8), and wave intensity (f=2). Seventeen students did not respond to this question. Figure 4 summarizes the themes and categories obtained for question 3.

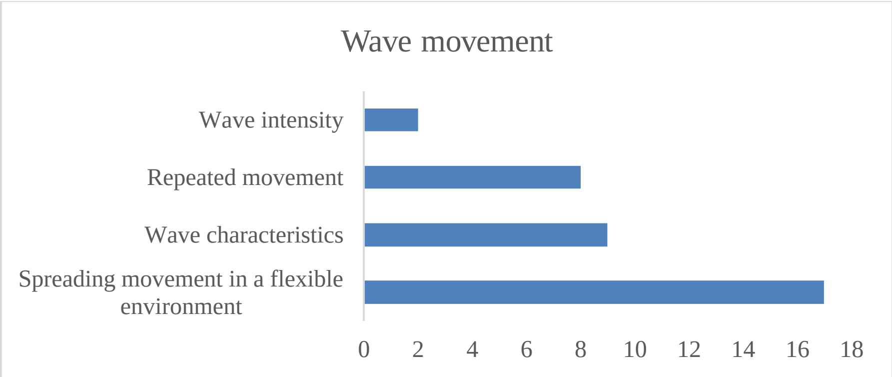


Figure 4: Themes for defining wave movement

Examples of teacher candidates' expressions of wave movement are given below.
S11"Mechanical shapes formed from the force we apply to the material from the inside or outside are called wave movements".
S24 "It is the vibration movement emitted in space or material environment".
S26 "It is the progress of the wave by travelling".
S34 "It is the movement that occurs due to regular advances in repetitive movements".
S36 "Movement from a source and formed in specific periods is called wave movement ".
S32 "It is the movement in environments such as air and water".

In the fourth question, the candidates were asked to draw a wave picture and show the characteristics they knew about it. Three categories emerged when the answers of the candidates who drew shapes were examined. For this question, there were only 2 drawings in which all the characteristics were shown correctly. There were also 28 drawings in which all characteristics were not shown, and 21 were incorrectly made drawings. Apart from this, two candidates made drawings. Figure 5 summarizes the themes and categories obtained for question 4.

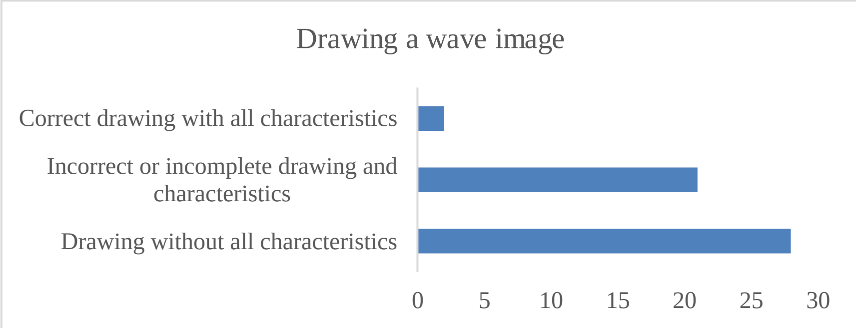
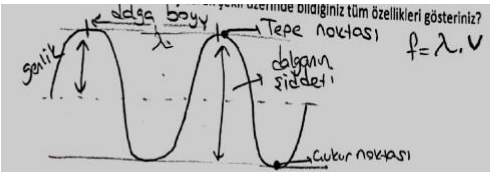


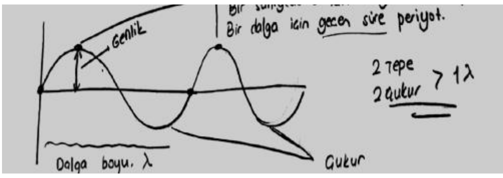
Figure 5: Categories for characteristics representation by drawing a wave image

Examples of characteristics representation by drawing a wave image:

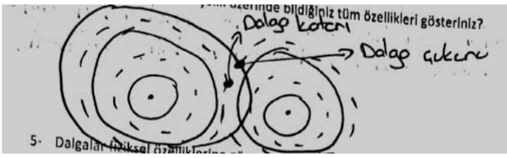
S17



S24



S48



Within the scope of the third sub-problem of the study, questions 5, 6, and 7 were asked to investigate the level of science teacher candidates' understanding and wave types. In the fifth question, it was asked to classify the waves according to their physical characteristics. When the answers were examined, it was seen that classifications were made according to the vibration direction (f=33), the direction and the energy they carry (f= 3), and the energy they carry (f=1). Still, there were also unclassified responses (f= 5). The sixth question asked about wave types and their examples. In the examination of the answers obtained, three themes emerged: electromagnetic (f= 44), mechanical (f= 40) and mechanical and electromagnetic (f= 3) wave examples. Under this question, 6 students gave unclassified examples. The seventh question asked about the characteristics of wave types. While there were only 2 complete answers in which the characteristics of wave types were given correctly, other answers were determined as mechanical and electromagnetic wave characteristics (f= 11), mechanical wave characteristics (f= 3), and electromagnetic wave characteristics (f= 3). Figures 6, 7, and 8 show the themes obtained for questions 5, 6, and 7.

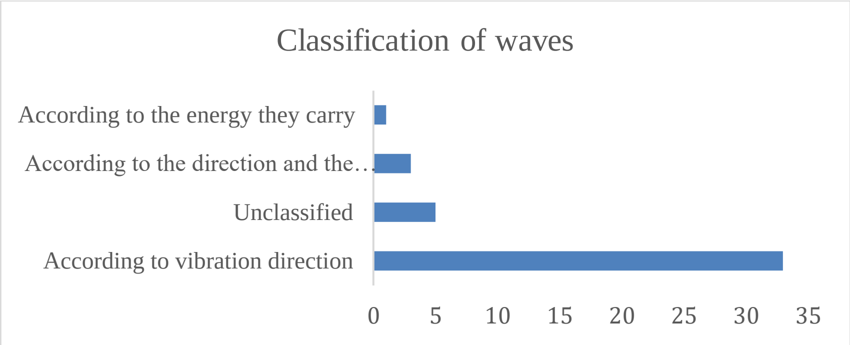


Figure 6: Themes for classifying waves according to their physical characteristics

Examples of teacher candidates' statements regarding questions 5, 6, and 7 are given below.
Examples of classification of waves according to their physical characteristics:
S6 "Transverse waves, longitudinal waves".
S10 "Water, spring waves, Em waves".
S44 "Classified according to vibration direction (transverse, longitudinal) and energy (mechanical and electromagnetic)".

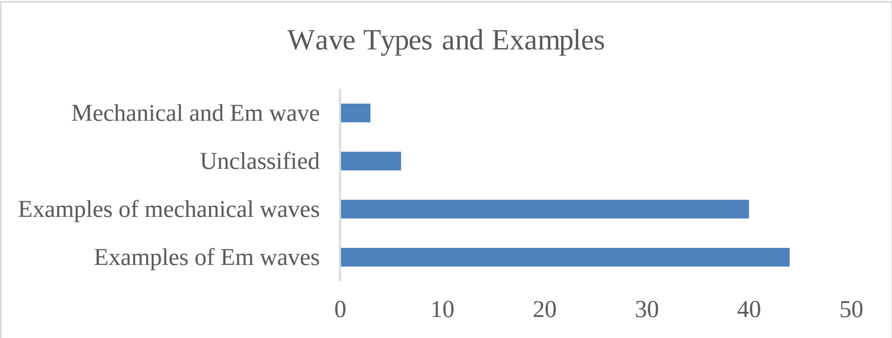


Figure 7: Themes for wave types and examples

Examples of wave types and examples
S19 "Sound, water and absorption wave".
S26 "Electromagnetic waves (radio, ultraviolet, x-ray, microwave) and mechanical waves (earthquake, water, spring, sound)".
S41 "Transverse waves(water wave), Longitudinal waves (Radio waves)".
S46 "Sound, earthquake, water wave".

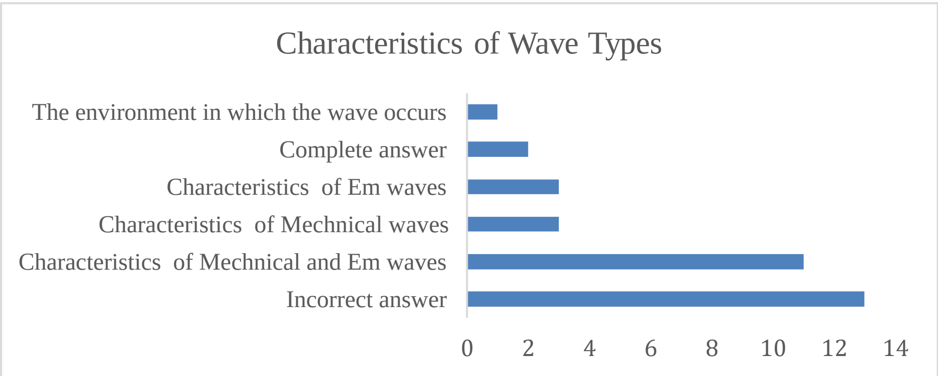


Figure 8: Themes for the characteristics of wave types

Examples of characteristics of wave types:
S8 "Water wave speed decreases while passing from deep to shallow environment".

S29 "Waves that need the environment for the spread of mechanical waves, electromagnetic waves, waves that spread without the need for the environment".
S51 "Waves in the MRI device may cause diseases in our body".

Within the scope of the fourth sub-problem of the study, questions 8, 9 and 10 were asked to investigate the level of science teacher candidates' understanding of the importance of waves. The eighth question asked about the importance of waves in our daily lives. In the examination of the answers were examined,6 themes emerged: their importance in communication (f=26), health services (f= 16), technology (f= 13), energy acquisition (f= 3), use in technological tools (f=1) and vision (f = 1). The ninth question asked examples of the waves encountered in daily life. In examining the answers obtained, statements like mechanical wave samples (f= 47) and electromagnetic wave samples (f= 42) were obtained. The tenth question, the last question, asked about the beneficial and harmful characteristics of the waves. Beneficial electromagnetic wave characteristics (f= 22) were determined as beneficial mechanical wave characteristics (f= 21), while harmful electromagnetic wave characteristics (f= 34) and harmful mechanical characteristics (f=19). Figures 9, 10, and 11 show the themes obtained for questions 8, 9, and 10.

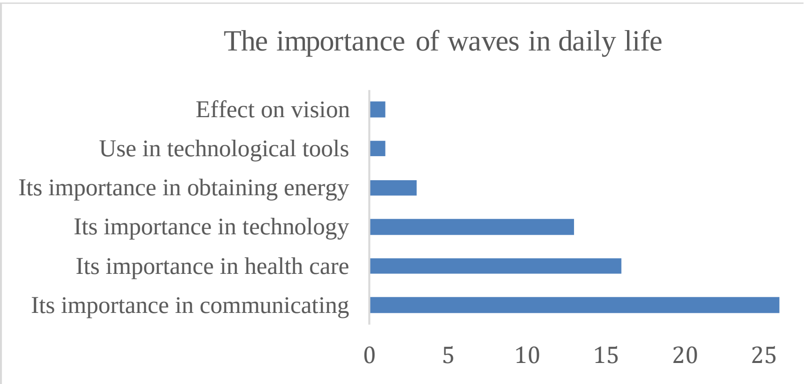


Figure 9: Themes for the importance of waves in daily life

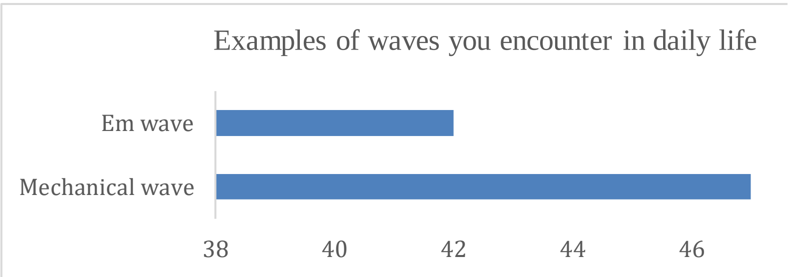


Figure 10: Themes for wave examples encountered in daily life

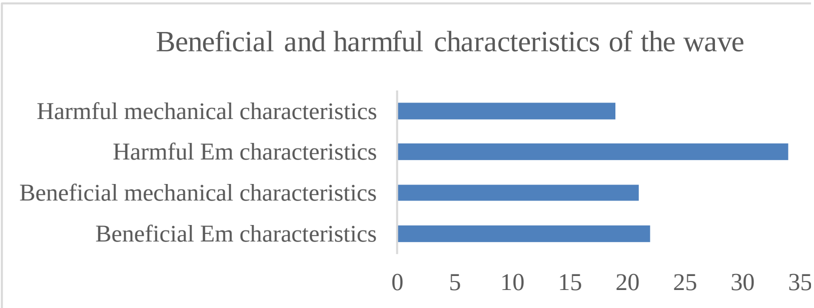


Figure 11: Themes for the beneficial and harmful characteristics of wa

Examples of teacher candidates' statements regarding questions 8, 9, and 10 are given below.
S5 "We obtain energy through waves".
S10 "Waves allow energy to be transported from one place to another, a beneficial characteristic".
S20 "Waves are frequently encountered in technological devices in the health field. In this respect, it is crucial."

S37 "Waves are important in our daily life because they spread as sound waves in our communication. Em waves are also important in medicine and chemistry".
S48 "Earthquake waves are essential in our daily life".
S29 "We can give examples of radio waves, microwave, topwater, arc, earthquake and infrared waves to the waves we encounter daily".
S30 "X-rays and gamma rays from Em waves are harmful to human health. The sound wave is vital in the diagnosis of diseases using ultrasound devices. "
S51"In our daily life, we encounter sound, light and water waves".

4. Discussion

The research questions were prepared to include conceptual, transactional, and relational categories (Durukan, 2019). Questions 1 and 3 in the data collection form were conceptual. The answers to these questions were evaluated as correct, incomplete, unscientific or no. Examples of correct answers to conceptual questions included S15(vibration), S23(wave), S24(wave movement), incomplete category S39(vibration), S51 (wave), S36(wave movement). The students mostly gave meaningless answers to conceptual questions, as seen in the examples of S20 (vibration) and S42 (wave), and S11(wave movement). These three concepts were related to each other. For example, wave and wave movement concepts cannot be understood without the vibration concept. Many students defined the wave concept as just a vibration or rising and falling movement inspired by the water or sound waves we often encounter daily. They could not use characteristics such as "Flexible environment", "Energy transferred to the Flexible environment", and "Shape change created in the environment while this energy is transmitted from one point to another" in their definition. Some of the students gave examples instead of conceptual explanations. In addition, they wrote the concepts of frequency, period, wavelength and amplitude related to the wave. The results of the study conducted with students at all levels on the wave concept revealed the difficulty of creating basic concepts related to waves and various misconceptions were determined (Wiyantara et al., 2021; Tumanggor et al., 2020; Admoko et al., 2019; Caleon & Subramaniam, 2013; Kennedy & de Bruyn, 2011; Küçüközer, 2010; Şengören et al., 2009).

Another remarkable situation is that all candidates tried defining mechanical waves. No student defined or explained the Em wave. Although there were mechanical and Em waves in the textbooks, the concept of the mechanical wave mostly came to the mind of the students.

Questions four, five, six, and seven were transactional, and the answers to these questions were evaluated as correct, incomplete, unscientific or no. As seen from the data in Figure 5, only two candidates could draw correctly (S17 and S24), whereas most candidates (such as S48) either made incomplete or incorrect drawings. Some candidates drew pictures of water waves, and some drew pictures of wave interference or wave diffraction patterns. This situation revealed an idea of the fundamental wave pattern in the candidates' minds. Besides, they had some deficiencies, such as the representation of the wave and the basic magnitudes of the wave. In their study with physics teacher candidates, Tumanggor et al. (2020) determined that the waves and wave movement represented by the graph were in their general characteristics as the biggest mistake, and then stated that they had misconceptions about wave frequency, wave source and environment characteristics, respectively. Enderle et al. (2021) stated that teachers relied on the effect of using the graphic models of the wave by using digital resources or simulations to understand different aspects of the wave structure of the students. They also stated that such practices would contribute to students' design skills (drawing waves) and using scientific models.

The fifth research question asked candidates to classify the waves according to their physical characteristics. Only three candidates could perform the classification correctly, for example, as in S44. Most of the candidates stated only one characteristic, such as direction. Few candidates answered according to their energy or by giving examples (S6, S10).

The sixth question asked about wave types and their examples. Only three students classified the waves as Em and mechanical waves and gave correct examples (S26). Most students did not make a classification and answered by giving almost equal mechanical wave or Em wave examples (S19, S46). A few students responded by stating transverse and longitudinal waves (T41).

In the seventh question, students were asked to write the characteristics of the wave types they gave as examples. Only three students stated that the environment was needed to spread mechanical waves and that the environment was not needed for spreading Em waves (S29). Many students only gave examples or incorrect answers (S51, S8). In general, the percentage of correct answers was relatively low in the operational questions of the candidates (Figure 6-8).

Questions 8, 9, and 10 aimed to explain the importance of waves, the examples we encounter daily, and their beneficial and harmful characteristics. All the candidates stated that it was essential and expressed it as communication, health and technology in order of importance. They gave more examples of mechanical waves from our daily lives. While issues such as communication, technology, health, and energy acquisition come to the forefront among the beneficial characteristics of waves, frequently stated ones were tsunami and earthquake waves in mechanical waves as harmful ones that may be caused by Em waves (gamma and x-rays) (such as their effect on human DNA, causing cancer). As a result of the examination of the explanations and examples made by the candidates, it can be said that they were more successful in the relational dimension depending on their daily life experiences.

According to the findings obtained, we can conclude that the candidates were far from giving a scientific explanation for the wave concept. In the 10th-grade physics lesson curriculum, the wave concept is considered mechanical waves, and subjects related to mechanical wave examples are included in detail as a separate section. Em waves are included in the physical classification of waves, but the formation mechanism is not included, and explanations are made by giving examples. Nevertheless, in the research, students had difficulty explaining the wave concept, which can be accepted as scientific. Besides, in the 11th-grade physics lesson curriculum, Em waves are discussed in detail in the wave mechanics unit and explained by giving examples. On the other hand, no student mentioned the definition or formation mechanism of the Em wave. They were satisfied only with giving examples. It may have been caused by deficiencies in understanding the formation of Em waves and their abstract nature.

Similar results have been obtained in studies conducted with all levels about waves. Wesono et al. (2018) stated that students tend to perceive physics as a problematic issue, mainly because of the abstract nature of the wave concept. Tongchai et al. (2009), on the other hand, stated that understanding the wave, which is a concept taught at the high school level for the first time, plays a vital role in physics, even if many subjects are not understood. Tumanggor et al. (2020) stated that misconceptions about mechanical waves and related concepts were determined, and special attention should be paid to eliminate them.

As a result, students need to understand what the wave concept is. Therefore, considering the existing misconceptions and deficiencies, reviewing the existing strategies to produce and use appropriate technological applications will be beneficial.

References

Admoko, S., Yantidewi, M., & Oktafia, R. (2019). The implementation of guided discovery learning using virtual lab simulation to reduce students' misconception of mechanical wave. In *Journal of Physics: Conference Series* (Vol. 1417, No. 1, p. 012089). IOP Publishing. https://doi.org/10.1088/1742-6596/1417/1/012089

Aykutlu, I., Bezen, S., & Bayrak, C., (2021). Pre-service teachers' conceptual understanding of the standing wave concept. *Turkish Journal of Education*, *10*(1), 1-22. https://doi.org/10.19128/turje.744113

Bao, L. & Koenig, K. Bao, L., & Koenig, K. (2019). Physics education research for 21 st century learning. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 1-12. https://doi.org/10.1186/s43031-019-0007-8

Barniol, P., & Zavala, G. (2017). The mechanical waves conceptual survey: An analysis of university students' performance, and recommendations for instruction. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(3), 929-952. https://doi.org/10.12973/eurasia.2017.00651a

Caleon, I., & Subramaniam, R. (2013). Addressing students' alternative conceptions on the propagation of periodic waves using a refutational text. *Physics Education*, *48*(5), 657. https://doi.org/10.1088/0031-9120/48/5/657

Chen, C., Sonnert, G., Sadler, P. M., Sasselov, D., &Fredericks, C. (2019). The impact of student misconceptions on student persistence in a MOOC. *Journal of Research in Science Teaching, 57*(6), 879-910. https://doi.org/10.1002/tea.21616

Creswell, J. W. (2014). *Qualitative, quantitative and mixed methods approaches.* Sage.
Day, S. B., & Goldstone, R. L. (2012). The import of knowledge export: Connecting findings and theories of transfer of learning. *Educational Psychologist*, *47*(3), 153-176. http://dx.doi.org/10.1080/00461520.2012.696438.
Durukan, Ü. G. (2019). *Elektrik akım konusuna yönelik tasarlanan adidaktik öğrenme ortamlarının lisans öğrencilerinin zihinsel modellerinin gelişimine etkisi.* [Unpublished Doctoral Dissertation]. Trabzon University.
Enderle, P., Margulieux, L., & King, N. (2021). Enderle, P., King, N., & Margulieux, L. (2021). What's in a wave: using modeling and computational thinking to enhance students' understanding of waves *The Science Teacher*, *88*(4), 24-28.
Erickson, H., L. Lanning and R. French (2017). *Concept-based curriculum and instruction for the thinking classroom (2nd ed.)*, Corwin.
Furqani, D., Feranie, S., & Winarno, N. (2018). The effect of predict-observe-explain (POE) strategy on students' conceptual mastery and critical thinking in learning vibration and wave. *Journal of science learning*, *2*(1), 1-8. https://doi.org/10.17509/jsl.v2i1.12879
Gülçiçek, Ç., Kizilci, H., & Damli, V. (2018). Effects of laboratory experiments on physics teacher candidates' wave concepts. *Physics Education*, *53*(5), 055018. https://doi.org/10.1088/1361-6552/aacd80
Harlen, W. (2010). *Principles and big ideas of science education*. Association of Science Education. Retrieved from https://www.ase.org.uk/bigideas
Kennedy, E. M., & de Bruyn, J. R. (2011). Understanding of mechanical waves among second-year physics majors. *Canadian Journal of Physics*, *89*(11), 1155-1161.
Küçüközer, H. A. (2010). Fen öğretmeni adaylarının dalgalar konusunda kavram yanılgıları. *Türk Fen Eğitimi Dergisi*, *7*(2), 66-75.
Miles, M. B., & Huberman, A. M. (2002). Reflections and advice. *The qualitative researcher's companion* (16). Sage.
Modell, H., Michael, J., & Wenderoth, M. P. (2005). Helping the learner to learn: the role of uncovering misconceptions. *The American Biology Teacher*, *67*(1), 20-26.
Neidorf, T., Arora, A., Erberber, E., Tsokodayi, Y., & Mai, T. (2020). Student misconceptions and errors in physics and mathematics: Exploring data from TIMSS and TIMSS advanced. IEA, Springer Open. https://doi.org/10.1007/978- 3-030-30188-0
Nieminen, P., Savinainen, A., & Viiri, J. (2012). Relations between representational consistency, conceptual understanding of the force concept, and scientific reasoning. *Physical Review Special Topics-Physics Education Research*, *8*(1), 010123.
Potvin, P., & Cyr, G. (2017). Toward a durable prevalence of scientific conceptions: Tracking the effects of two interfering misconceptions about buoyancy from preschoolers to science teachers. *Journal of Research in Science Teaching*, *54*(9), 1121–1142. https://doi.org/10.1002/tea.21396
Resbiantoro, G., & Setiani, R. (2022). A review of misconception in physics: the diagnosis, causes, and remediation. *Journal of Turkish Science Education*, *19*(2). 403-427. https://doi.org/10.36681/tused.2022
Şengören, S. K., Tanel, R., & Kavcar, N. (2009). Students' difficulties about the wave pulses propagating on a rope. *Journal of Turkish Science Education (TUSED)*, *6*(1), 50-59.
Taşlıdere, E. (2021). Relative effectiveness of conceptual change texts with concept cartoons and 5E learning model with simulation activities on pre-service teachers' conceptual understanding of waves. *Participatory Educational Research*, *8*(4), 215-238. https://doi.org/10.17275/per.21.87.8.4
Tongchai, A., Sharma, M. D., Johnston, I. D., Arayathanitkul, K., & Soankwan, C. (2009). Developing, evaluating and demonstrating the use of a conceptual survey in mechanical waves. *International Journal of Science Education*, *31*(18), 2437-2457.
Tumanggor, A. M. R., Kuswanto, H., & Ringo, E. S. (2020). Using four-tier diagnostic test instruments to detect physics teacher candidates' misconceptions: Case of mechanical wave concepts. In *Journal of physics: conference series* (Vol. 1440, No. 1, p. 012059). IOP Publishing. https://doi.org/10.1088/1742-6596/1440/1/012059
Wescone,A.M., Timothy,N., & Prosper, A. D. N. (2018). Effects of Analogy Instructional Strategy on Students' Performance in Wave Concept. *Journal of Education and Practice*. *9*(5),111-119. Retrieved from https://core.ac.uk/download/pdf/234641386.pdf
Wiyantara, A., Widodo, A., & Prima, E. C. (2021, March). Identify students' conception and level of representations using five-tier test on wave concepts. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012137). IOP Publishing. https://doi.org/10.1088/1742-6596/1806/1/012137
Xie, L., Liu, Q., Lu, H., Wang, Q., Han, J., Feng, X., & Bao, L. (2021). Student knowledge integration in learning mechanical wave propagation. *Physical Review Physics Education Research*, *17*(2), 020122. https://doi.org/10.1103/PhysRevPhysEducRes.17.020122