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Mechanical Wave Concepts of Thai High School Students: Comparing Learned and Unlearned Groups

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Abstract

Mechanical waves are one of the basic topics of physics; they are also the basis of various fields such as physical optics, geophysics, engineering, and medical physics. This study aims to investigate the mechanical wave concepts of Thai high school students. Participants were 150 grade 11 – 12 students from a high school in Songkhla Province, Thailand. They were divided into two groups. The first group consisted of 77 students – grade 12 who had already learned about mechanical waves, and the second group consisted of 73 students – grade 11 who had not yet learned about the topic. The main instrument was the Mechanical Wave Conceptual Survey (Tongchai, Sharma, Johnston, Arayathanitkul & Soankwan, 2009) which consisted of 22 multiple-choice questions. The researchers also asked students to provide their reasoning for choosing their answers for each multiple-choice question. The survey was administered to students and they were given 50 minutes to complete it. Students' answers and their reasoning were analyzed quantitatively and qualitatively. As a result, students' responses were categorized into four main topics: 1) propagation; 2) superposition; 3) reflection; and 4) standing waves. Responses from both groups of students indicated the same misconceptions.

Introduction

Learning mechanics of waves is important for a variety of reasons, some of which include: Understanding the natural world: Waves are fundamental to the functioning of many natural systems, from the motion of the oceans to the behavior of light and sound. Studying mechanics of waves helps us to better understand these systems and how they work (Jaisuk, Tipparach, & Tanahoung, 2010). Technology and engineering: Waves are also critical to many modern technologies, such as telecommunications, medical imaging, and seismic detection. By understanding the mechanics of waves, we can design and build more advanced and effective technologies. Problem-solving: Learning mechanics of waves involves developing a range of analytical and problem-solving skills, such as mathematical modeling, data analysis, and experimentation. These skills can be applied to a wide range of other fields and challenges. Career opportunities: Finally, an understanding of mechanics of waves can be valuable in many careers, such as in engineering, physics, and geology. Mastery of this topic can open up a range of job opportunities and help one to be more competitive in the field.
There are several common misconceptions about mechanics of waves in physics education research (Kryjevskaia, Stetzer, & Heron, 2012; Sangpradit, 2015; Tongchai, Sharma, Johnston, Arayathanitkul, & Soankwan, 2011; Wittmann, 2002; Wittmann, Steinberg, & Redish, 1999)

some of which include: Waves are always visible: Many students believe that waves are always visible, like water waves, but this is not true. In fact, many waves are invisible, such as sound waves, radio waves, and X-rays. Waves move the medium: Some students think that waves move the medium they are traveling through, but this is also not accurate. Waves transfer energy through the medium, but they do not necessarily move the medium. Waves require a medium: While some waves do require a medium to travel through, such as sound waves, others do not, such as electromagnetic waves. Waves travel in a straight line: Some students believe that waves always travel in a straight line, but this is not true in all cases. Waves can be diffracted, reflected, or refracted, depending on the properties of the medium they are traveling through. Finally: wave speed is fixed: some students believe that the speed of a wave is always fixed, but this is not accurate. The speed of a wave might depend on a range of factors, such as the properties of the medium, the frequency of the wave, and the amplitude of the wave.
The theory of conceptual change is a framework for understanding how learners modify or replace their existing ideas and understandings about a topic with new, more accurate, and scientifically valid concepts. In the context of physics education, conceptual change theory helps to explain why students often hold onto misconceptions and misunderstandings about physical phenomena, and how these misconceptions can be replaced with more scientifically accurate knowledge. According to conceptual change theory, students often develop their own personal theories or mental models about how the world works, based on their experiences and observations (Dykstra JR., Boyle, & Monarch, 1992). These mental models can sometimes be incorrect or incomplete and may not align with scientific explanations of physical phenomena. When students encounter new information or experiences that challenge their existing mental models, they may experience cognitive conflict, confusion, or even resistance to new ideas. To promote conceptual change in physics education, instructors can use a variety of strategies to help students identify and revise their misconceptions (Hewson & Hewson, 1983). Some of these strategies include: Providing explicit instruction: by providing clear explanations, examples, and demonstrations, instructors can help students build accurate mental models of physical phenomena (Tongchai, Sharma, Johnston, & Arayathanitkul, 2008). Engaging in active learning: Active learning strategies, such as problem-based learning or inquiry-based learning, can help students to develop more accurate mental models by encouraging them to explore and test their ideas through hands-on experiences. Encouraging metacognition: By prompting students to reflect on their thinking and identify their own misconceptions, instructors can help students to become more aware of their own mental models and identify areas where revision is needed. Providing feedback: Feedback from instructors or peers can help students to identify and correct their misconceptions by providing them with information about the accuracy of their mental models. Overall, the theory of conceptual change provides a useful framework for understanding how learners construct and revise their knowledge about physical phenomena and can help instructors to design more effective physics education interventions.
Herein, the misconceptions of students are investigated in this study, which will examine mechanical wave concepts by using the Mechanical Wave Conceptual Survey (Tongchai et al., 2009), the standard survey used in physics education research. The findings were provided to Thai high school students from Songkhla province, Thailand, and compared their responses between two groups: those who have previously learned the topic and those who had not. These misunderstandings will be used for finding methods, processes, or innovative tools that enhance the learning to achieve long-term understanding and change into the right concepts in the next chapter.

Review Literature

Students' conceptions and misconceptions

The term "conception" in the sense refers to students' knowledge about how the world works or how it is constituted, which is operative in different situations. (Dykstra JR. et al., 1992). Purdie and Hattie (2002) and Säljö (1979) agree that students perceive learning in two qualitatively different ways. First, a surface conception of learning involves remembering and using information conceptions (the increase of knowledge, memorizing, and the acquisition of facts, procedures, and others, which can be retained and/or utilized in practice). Secondly, a deep conception of learning involves the understanding conception (the abstraction of meaning and an interpretative process aimed at the understanding of reality).

Students have conceptions about physical phenomena before entering a physics class. The conceptions formed by students to explain physical phenomena may not agree with the models of physical phenomena scientists have developed based on experimentation (Wuttiprom, 2018). However, the students' models may be valid in certain cases. In order for students to alter their conceptions to agree with experimental observations, it is necessary to understand their pre-conceptions and develop materials that will present them with experimental evidence that challenges their conceptions, compelling them to alter their conceptions (Laws, Sokoloff, & Thornton, 1999; Thornton & Sokoloff, 1998).

Misconceptions, on the other hand, defined as incorrect interpretations or misunderstandings of an idea, concept, or process, are often a large part of students' prior knowledge (Marrs, Blake, & Gavrin, 2003). Misconceptions can be described in Barriers to Understanding Science (Committee on Undergraduate Science Education, 1997), categorized as follows:

- Preconceived notions: forming an opinion prior to actual knowledge or experience.
- Non-scientific beliefs: from religious or mythical teachings.
- Conceptual misunderstandings: incomplete or over-simplified knowledge from previous science courses.
- Vernacular misconceptions: uncertainty about differences between the popular vs. the scientific use of words like work or theory.
- Factual misconceptions: falsities learned at an earlier time and retained.

The development of students' scientific concepts is considered an important goal of science teaching and learning management. Wuttiprom (2018) said students encounter difficulties changing their preconceived ideas, which differ from accepted scientific theory; this is often called alternative conception or misconception and these ideas disrupt the learning process. Preconceived ideas can hinder the reception of new scientific concepts. The learning environment, including experience, and social and cultural aspects, can influence the reception of scientific concepts (Committee on Undergraduate Science Education, 1997).

Mechanical Wave Conceptual Survey (MWCS)

In Physics Education Research (PER), examining learners' understanding of key concepts in physics content relies on standardized research tools. In 1998, Wittmann first created a device of this type called the Wave Diagnostic Test (WDT) in the form of open-ended questions (Wittmann, 1998). Subsequently, the test was developed by Apisit Tongchai and his colleagues between 2007 and 2009 over a 2-year period by using data from open-ended questions and additional interviews with the samples in Thailand and Australia (Tongchai et al., 2009). Based on the results of the research, the final version of a multiple-choice conceptual survey was created and called the Mechanical Waves Conceptual Survey (MWCS), in which standard statistical analysis showed that the survey is reliable and valid, using the Thai version in this study.

Tongchai et al. (2009) introduced the Mechanical Waves Conceptual Survey (MWCS) that evaluates university students' understanding of four main topics: propagation, superposition, reflection, and standing waves. This is the most important test of its kind to date. The test has 22 multiple-choice questions, 17 of them have a traditional multiple-choice format with different numbers of options (A – H) and five have a "two-tier" format: Questions 17, 18, 19, 21, and 22, which students have to choose an answer and one of justification for each question. Each question was given a score of 1 and 0 (out of 22 points). The multiple-choice questions considered the correct answer selection, whereas the two-tier questions need both the answer and justification correct to be scored. A grouping of main topics and subtopics of the MWCS are shown in Table 1.

Table 1. Grouping of Main topics and subtopics of the MWCS.

Category	Main Topic	Subtopic	Question item
1	Propagation	Sound variables	1
		Speed of sound waves	2
			3
		Speed of waves on strings	4
			5
		Displacement of medium in sound waves	6
			7
			8
2	Superposition	Superposition-Construction	9
			10
		Superposition-Destruction	11
			12
3	Reflection	Reflection-Fixed end	13
			15
		Reflection-Free end	14
			16
4	Standing waves	Transverse standing waves in strings	17
			18
			19
		Longitudinal standing waves in sound	20
			21
			22

Methodology

This study was a pre-experimental design with Thai students who studied in a high school in Songkhla Province, a school in the south of Thailand. Participants were categorized into two groups depending on students who learned and unlearned the topic of the wave. The instrument in this study used the MWCS in the Thai version (Tongchai et al., 2009). Data was collected from a total of 150 students in the first semester of the academic year 2022. The samples consisted of 77 Grade 12 students who have already learned about wave topics through the traditional method and another group of 73 Grade 11 students who have not yet learned this topic. Both groups of students were tested using the MWCS for the same 50 minutes. The collection of data obtained from the assessment was analyzed both quantitatively and qualitatively. The quantitative dimension analyzed the percentage of correct and incorrect answers of students and the average scores from this assessment in each group. The qualitative assessment, on the other hand, analyzed the content of the student's chosen answers, along with the student's rationale that may be further explained in each question item to provide students with ideas on the matter. The operating process in this study follows the principle of the Deming cycle (Alauddin & Yamada, 2019; Deming, 2018; O'Neil, 1993; Rita & Lakshmi, 2009; Shyng, 2021). It consists of 4 steps: Plan (P), Do (D), Check (C), and Act (A), which are shown in Figure 1.

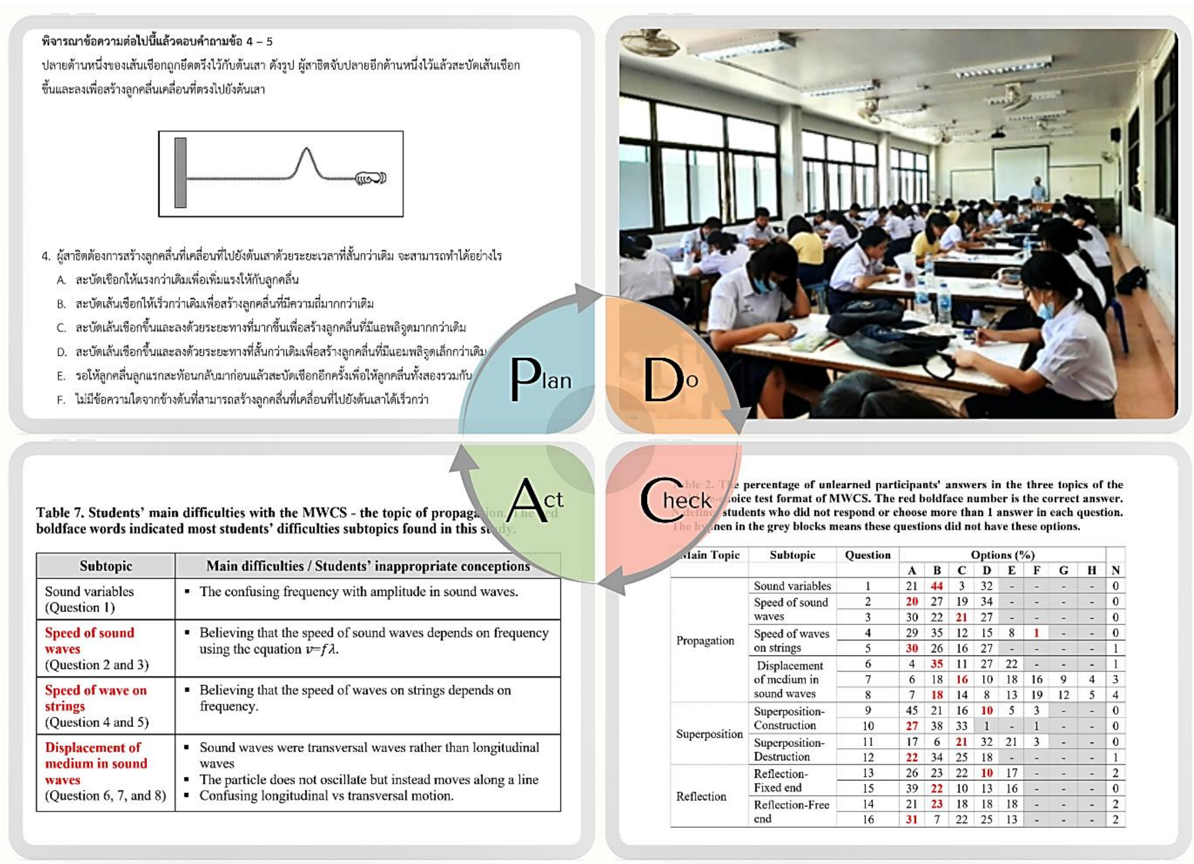

Figure 1. PDCA processes integrated into the pre-experimental research design

According to Figure 1, a pre-experimental research design using PDCA processes was used in this study:

1) Plan (P): The standard survey of MWCS was planned and prepared in the Thai version, which consists of 22 questions, for examining students.
2) Do (D): The MWCS was done by each student group within 50 minutes, and then the data was collected by the researcher from this survey.
3) Check (C): The students' answers were checked by the researcher for finding the percentage of students' performance in each topic and subtopic on MWCS.
4) Act (A): The students' main difficulties with the wave topic were analyzed from the students' answers and compared the student's conceptual understanding between the learned and unlearned groups.

Findings

Students' performance on MWCS

All students' average scores obtained on the MWCS from this study (n = 150) is 4.69 (21.33%). Each student group shows that the average score of unlearned students (n = 77) is 4.05 (18.42%) whereas the average score of learned students (n = 73) is 5.37 (24.41%). Even if the average scores of groups were evaluated with the independent samples t-test showing that the learned group had an average score significantly higher than the unlearned (sig. < .05) both of them still have a low score of MWCS (< 50%), indicating that the test is difficult for all students. Moreover, the distribution of scores was significantly non-normal. These findings are shown in the tables below.

Table 2. The percentage of unlearned participants' answers in the three topics of the multiple-choice test format of MWCS. The red boldface number is the correct answer. N defines students who did not respond or choose more than 1 answer in each question. The hyphen in the grey blocks means these questions did not have these options.

Main Topic	Subtopic	Question	Options (%)								N
			A	B	C	D	E	F	G	H	N
Propagation	Sound variables	1	21	**44**	3	32	-	-	-	-	0
	Speed of sound waves	2	**20**	27	19	34	-	-	-	-	0
		3	30	22	**21**	27	-	-	-	-	0
	Speed of waves on strings	4	29	35	12	15	8	**1**	-	-	0
		5	**30**	26	16	27	-	-	-	-	1
	Displacement of medium in sound waves	6	4	**35**	11	27	22	-	-	-	1
		7	6	18	**16**	10	18	16	9	4	3
		8	7	**18**	14	8	13	19	12	5	4
Superposition	Superposition-Construction	9	45	21	16	**10**	5	3	-	-	0
		10	**27**	38	33	1	-	1	-	-	0
	Superposition-Destruction	11	17	6	**21**	32	21	3	-	-	0
		12	**22**	34	25	18	-	-	-	-	1
Reflection	Reflection-Fixed end	13	26	23	22	**10**	17	-	-	-	2
		15	39	**22**	10	13	16	-	-	-	0
	Reflection-Free end	14	21	**23**	18	18	18	-	-	-	2
		16	**31**	7	22	25	13	-	-	-	2

Table 3. The percentage of unlearned participants' answers in the last topics of the 2-tier diagnostic format of MWCS – questions 17, 18, 19, 21, and 22 - except question 20. The red boldface is the correct answer. It also shows the five most frequently incorrect students' answers. "Others" defines students who responded in less-frequent combination answers. N defines students who did not respond or choose more than 1 answer in each question. For example, "C-3" means the first "C" as the answer and the second "3" as the justification.

Main topic	Subtopic	Question	Options (%)						
Standing waves	Transverse standing waves in strings	17	C-3	A-1	A-2	B-3	B-2	**B-4**	Others
			17	16	13	10	8	**8**	28
		18	B-4	**A-3**	A-4	C-1	B-3	B-1	Others
			21	**14**	13	9	7	5	31
		19	**B-3**	B-4	C-1	A-3	A-4	A-1	Others
			25	16	14	6	6	4	29
	Longitudinal standing waves in sound	20	A	B	C	D	E	**F**	N
			9	25	4	54	3	**3**	2
		21	B-4	B-1	A-2	A-3	B-3	**C-4**	Others
			21	17	10	5	4	**1**	42
		22	C-5	C-3	C-4	C-2	A-1	**B-2**	Others
			26	13	8	6	4	**3**	40

Table 4. The percentage of learned participants' answers in the three topics of the multiple-choice test format of MWCS. The red boldface number is the correct answer. N defines students who did not respond or choose more than 1 answer in each question. The hyphen in the grey blocks means these questions did not have these options.

Main Topic	Subtopic	Question	Options (%)								N
			A	B	C	D	E	F	G	H	N
Propagation	Sound variables	1	12	**38**	7	43	-	-	-	-	0
	Speed of sound waves	2	**10**	55	27	8	-	-	-	-	0
		3	15	45	**27**	11	-	-	-	-	2
	Speed of waves on strings	4	17	38	19	15	8	**3**	-	-	0
		5	**34**	21	18	27	-	-	-	-	0
	Displacement of medium in sound waves	6	7	**20**	36	29	8	-	-	-	0
		7	14	12	**20**	7	19	7	19	1	1
		8	6	**16**	5	21	10	27	10	4	1
Superposition	Superposition-Construction	9	30	22	8	**29**	4	7	-	-	0
		10	**55**	25	20	-	-	-	-	-	0
	Superposition-Destruction	11	18	20	**34**	18	10	-	-	-	0
		12	**51**	26	11	12	-	-	-	-	0
Reflection	Reflection-Fixed end	13	10	30	8	**38**	14	-	-	-	0
		15	37	**15**	7	27	14	-	-	-	0
	Reflection-Free end	14	10	**26**	**12**	**30**	22	-	-	-	0
		16	**22**	4	**29**	**18**	27	-	-	-	0

Table 5. The percentage of learned participants' answers in the last topics of the 2-tier diagnostic format of MWCS – questions 17, 18, 19, 21, and 22 - except question 20. The red boldface is the correct answer. It also shows the five most frequently incorrect students' answers. "Others" defines students who responded in less-frequent combination answers. N defines students who did not respond or choose more than 1 answer in each question. For example, "C-3" means the first "C" as the answer and the second "3" as the justification.

Main topic	Subtopic	Question	Options (%)					
Standing waves	Transverse standing waves in strings	17	**B-4**	**C-3**	**A-2**	**B-2**	**A-3**	**A-1**	**Others**
			34	14	12	7	6	4	23
		18	**B-4**	**A-3**	**A-4**	**C-1**	**B-3**	**C-2**	**Others**
			20	**18**	15	10	8	8	21
		19	**B-3**	**B-4**	**A-3**	**A-4**	**C-2**	**B-2**	**Others**
			29	19	8	7	7	5	25
	Longitudinal standing waves in sound	20	**A**	**B**	**C**	**D**	**E**	**F**	**N**
			6	33	4	49	7	**1**	0
		21	**B-4**	**A-2**	**B-5**	**B-1**	**C-5**	**C-4**	**Others**
			20	10	10	8	8	**8**	36
		22	**C-3**	**C-2**	**C-5**	**C-4**	**B-2**	**B-3**	**Others**
			25	18	14	11	**8**	4	20

Based on data from Tables 2 and 3, most students in the unlearned group chose the common correct answers for 6 out of 22 questions, accounting for 27.27% of responses. Similarly, in Tables 4 and 5, the learned group chose more than two of the common correct answers for 8 out of 22 questions, which was 36.36%. Despite this, both groups of students still answered less than half of the questions correctly. Questions 5 and 19 were correctly answered by both groups, while most other questions were answered incorrectly.
In analyzing the data from all four tables, no significant differences were found in the trends of the students' answers. It appears that a considerable number of students in both groups did not provide additional reasons for their answers, even though space was provided for explanations in the assessment. Instead, they relied solely on the given options, and this behavior is evident in the sample student answer sheet in the supplementary material. This suggests that some students may have guessed the answers or misunderstood the content, which will be discussed further in the next section.

Students' main difficulties with MWCS

For all results of the student's performance on MWCS, we evaluated the data considering the correct and incorrect answers in both learned and unlearned groups. The data were focused on the most correct and wrong answers chosen by participants of two groups. This data indicated the students' main difficulties with MWCS in each main topic and subtopic, shown in Table 6. The checkmark is defined as the correct answer chosen by most students, on the other hand, the cross is interpreted as the wrong answer chosen by most students.

Table 6. The most difficult questions for the learned and unlearned groups.

Category	Main Topic	Subtopic	Question item	Learned	Unlearned
1	Propagation	Sound variables	1	✗	✓
		Speed of sound waves	2	✗	✗
			3	✗	✗
		Speed of waves on strings	4	✗	✗
			5	✓	✓
		Displacement of medium in sound waves	6	✗	✓
			7	✓	✗
			8	✗	✗
2	Superposition	Superposition-Construction	9	✗	✗
			10	✓	✗
		Superposition-Destruction	11	✓	✗
			12	✓	✗
3	Reflection	Reflection-Fixed end	13	✓	✗
			15	✗	✗
		Reflection-Free end	14	✗	✓
			16	✗	✓
4	Standing waves	Transverse standing waves in strings	17	✓	✗
			18	✗	✗
			19	✓	✓
		Longitudinal standing waves in sound	20	✗	✗
			21	✗	✗
			22	✗	✗

Table 6 illustrated the 10 most difficult questions for learned and unlearned students, it notes that they come primarily from two main topics. Questions 2, 3, 4, and 8 are from propagation, and questions 18, 20, 21, and 22 are from the standing wave. In addition, questions 9 and 15 fall under each topic of superposition and reflection, respectively. These findings can be divided into four major categories of mechanical wave misconceptions, with the average percentage of misconceptions (equal to 100% - average percentage of correct answers for each main topic in Table 2-5) shown in Figure 2.

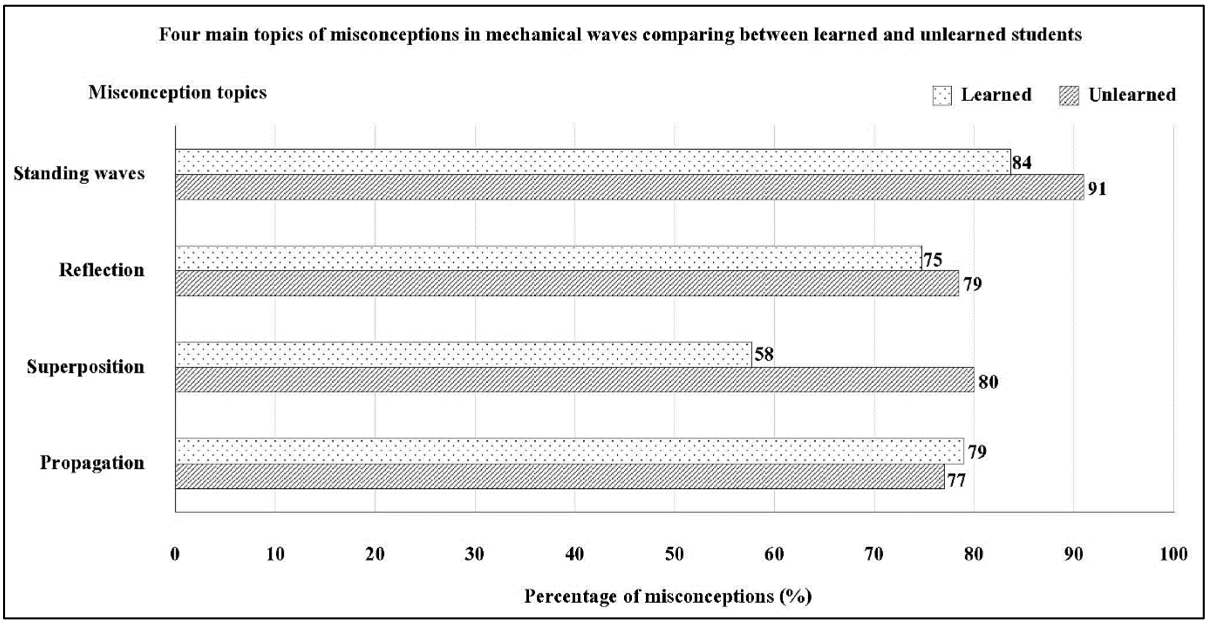

Figure 2. The percentage of mechanical wave misconceptions of four main topics.

Figure 2 indicated that there is still a high percentage of misunderstanding about mechanical wave contents in both groups (more than 55%). Except for the superposition topic, the graph shows that the percentage of misconceptions between learned and unlearned groups is not significantly different. Considering the main topics, it was found that students who had not yet learned (blue bar) also had more misunderstandings than learned students (orange bar) to three topics (superposition, reflection, and standing wave), except for the topic propagation. In this topic, the percentage of misconceptions among the students who had learned was higher than another, but it was not more different. (79% of learned and 77% of unlearned). This showed that students who had not yet learned waves overall had higher misunderstandings than those who had learned it. The main topics that were problematic for both groups of students were sorted by percentage of misconceptions as the most problematic topic was standing wave, followed by propagation, reflection, and superposition, respectively.

Discussion

The study analyzed responses from both groups of students on the MWCS (Tables 2 – 5) and conducted content analysis on their reasons provided in some questions. Misunderstandings and inappropriate conceptions were identified, categorized by question topics and subtopics within the four main waves topics (Tables 7 – 10). These misconceptions were consistent across both learner groups. Detailed student responses and ideas can be found in Supplementary Material B.

Table 7. Students' main difficulties with the MWCS - the topic of propagation. The red boldface words indicated most students' difficulties subtopics found in this study.

Subtopic	Main difficulties / Students' inappropriate conceptions
Sound variables (Question 1)	▪ The confusing frequency with amplitude in sound waves.
Speed of sound waves (Question 2 and 3)	▪ Believing that the speed of sound waves depends on frequency using the equation $v=f\lambda$.
Speed of wave on strings (Question 4 and 5)	▪ Believing that the speed of waves on strings depends on frequency.
Displacement of medium in sound waves (Question 6, 7, and 8)	▪ Sound waves were transversal waves rather than longitudinal waves ▪ The particle does not oscillate but instead moves along a line ▪ Confusing longitudinal vs transversal motion.

Table 8. Students' main difficulties with the MWCS - the topic of superposition. The red boldface words indicate the subtopics students found most difficult in this study.

Subtopic	Main difficulties / Students' inappropriate conceptions
Superposition-Construction (Question 9 and 10)	▪ Lacks the precision to be considered correct ▪ Choosing an answer which demonstrates the lack of a complete understanding
Superposition-Destruction (Question 11 and 12)	▪ Considering that waves will become smaller because they lose energy when colliding

Table 9. Students' main difficulties with the MWCS - the topic of reflection. The red boldface words indicate the subtopics students found most difficult in this study.

Subtopic	Main difficulties / Students' inappropriate conceptions
Fixed-end (Question 13 and 15)	▪ With no vertical inversion which means a pulse with an incorrect leading edge (both types) ▪ In the complete reflections (both types), choose a reflected pulse on the correct side of the string but with no vertical inversion ▪ In the half-reflections (both types), choose a half-reflected pulse on the same side of the string as the complete reflected pulse ▪ Think of a pulse reflected on the right side of the string (both types).
Free-end (Question 14 and 16)	

Table 10. Students' main difficulties with the MWCS - the topic of standing waves. The red boldface words indicated the subtopics students found most difficult in this study.

Subtopic	Main difficulties / Students' inappropriate conceptions
Transverse standing waves on a string (Question 17, 18, and 19)	▪ A justification errors ▪ To predict the opposite of the correct answer, but to select the correct justification ▪ Predicting and giving justifications regarding the changes in the wavelength of the harmonic when, in the physical situation, the frequency, the tension, and the density are changed.
Longitudinal standing waves in sound (Question 20, 21, and 22)	▪ Had difficulties with the shape of the wavelength ▪ Comparing the wavelengths of the same harmonic in the same tube ▪ Knew that the wavelength changed but did not understand the way in which it had changed ▪ Confusing displacement nodes with pressure nodes and displacement antinodes with pressure antinodes.

Tables 7 and 10 revealed the most challenging questions for both learned and unlearned students, covering propagation and standing waves, along with specific subtopics. These findings align with previous research by Barniol and Zavala (2017), which showed these topics as difficult for university students despite learning them in high school. Tables 8 and 9 further identified misconceptions about Superposition-Construction (Question 9) and Fixed-end reflection (Question 15). While students grasped principles, visualization posed difficulties. Only two subtopics had a majority of correct answers: Speed of wave on strings (Question 5) and Transverse standing waves on a string (Question 19). However, the overall proportion of correct answers for these subtopics remained below 40%.

Figure 2 shows a high percentage of misunderstanding about mechanical wave concepts in both groups. The study identifies prior knowledge as a challenge for unlearned students and traditional teaching methods as a hindrance for the learned group. These misunderstandings stem from past experiences and teaching approaches that prioritize knowledge transfer rather than student engagement (Luft & Roehrig, 2007; Redish, 2004; Şen & Sarı, 2018). To improve learning outcomes, science education should adopt active learning methods like the 5E Teaching model, Interactive simulation, Interactive Lecture Demonstrations, and Heterogeneous lecturing styles, which can address pre-existing misconceptions and minimize their formation (Georgiou & Sharma, 2020; Nicetas, Villarino, & Villarino, 2018; Sarı, Hassan, Güven, Ömer, & Şen, 2017).

The study's findings demonstrate that a significant number of students, especially those in grade 12, retain misconceptions about the topic even after instruction. This suggests that their learning is primarily driven by rote memorization rather than genuine comprehension, leading to only short-lived understanding (Sayre, Franklin, Dymek, Clark, & Sun, 2012; Semb, Ellis, & Araujo, 1993; Tongchai, Arayathanitkul, & Soankwan, 2007). Moreover, the prevalence of these misconceptions persists over time, possibly due to the traditional classroom approach that heavily relies on lectures, promoting memorization rather than deeper understanding. These intriguing results underscore the importance of using these findings as a foundation for further research, with the aim of developing effective strategies or tools to foster long-term, meaningful understanding in students, while also rectifying the prevalent misunderstandings (Deslauriers & Wieman, 2011).

Conclusion

These preliminary results attractively evidenced that the mechanical wave concept of learners may be influenced by prior knowledge, experience, and teaching method. Particularly, instructional styles also had a long-term impact on student understanding, as clearly shown by the percentage of misconception, with no significant difference in both student groups (learned and unlearned). Hence, teaching method modification or new educational intervention may improve meaningful student understanding more than the traditional approach. These are our interests for future studies.

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