Assessing Novice Preservice Physics Teachers' Conceptual Knowledge of Mechanical Waves

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***Abstract*: Current research in physics shows that undergraduate students have poor conceptual knowledge of waves and optics. This research seeks to assess novice preservice physics teachers' conceptual understanding of mechanical waves using qualitative and quantitative approaches. Year one semester two (Y1,2) preservice physics teachers in a university in Uganda were exposed to a standardized multiple choice question (MCQ) assessment test- Mechanical Waves Conceptual Survey 2 (MWCS2). The descriptive quantitative analysis of novice preservice physics teachers'(NPPT) responses to the MCQ assessment test was taken beyond the conventional responses of assessing the correct options by considering how their responses to the multiple choice were distributed. Interpretive qualitative analysis was used to interpret the responses to each question in order to determine what informed NPPT responses to each question. The interpretation of both qualitative and quantitative data was combined to make sense of scientific conceptions, alternative conceptions, and misconceptions upheld by the preservice teachers. The findings and the distributions showed that novice preservice physics teachers' conceptual understanding and knowledge of mechanical waves are poor. Implications for teaching and learning mechanical waves amongst NPPT in view of their future professional practice were identified.**

***Keywords*: Novice, Preservice, Conceptual knowledge**

I. INTRODUCTION

Topics in mechanical waves are major concepts that are taught yearly among first-year undergraduate physics and science education students in universities. The study of mechanical waves occupies a privileged position and many areas of advanced physics (light, heat sound, electro-magnetism, etc.) and other areas outside physics (spectroscopy, meteorology. Electrical engineering, etc.) depend on a solid understanding of why and how disturbances propagate in the manner of a wave. An understanding of mechanical waves is fundamental and it is important for making sense of physical optics, quantum mechanics, electromagnetic radiation and other courses to be taught in the subsequent semesters. It is, therefore, important to ensure that the preservice teachers have a good grasp of conceptual knowledge of mechanical waves as the teachers' progress in their studies and career training. There has been much research on mechanical waves among undergraduate students in universities (Barniol & Zavala, 2017; Eshach, 2014; Kryjevskaia, Stetzer, & Heron, 2012; Olaniyan & Govender 2020; Pejuan, Bohigas, Jaén, & Periago, 2012; Zeng et al., 2014; Ringo & Mulvia, 2022). Over the years most of this research focused on the cognitive aspect of students understanding of mechanical waves. Bezen and Bayrak, 2020 researched on teaching mechanical wave by inquiry-based teaching and Kennedy and de Bruyn (2011) did a quantitative study using the Wave Diagnostic Test to investigate the reasoning of first- and second-year physics students about mechanical waves. Barniol and Zavala (2017) carried out a qualitative analysis of 541 university student' performance using mechanical waves conceptual survey (MWSC). The mechanical waves conceptual survey consists of 22 questions (17 multiple choices and 5 two tiers questions), the questions cover four topics which are propagation, superposition, reflection, and standing waves. The study of Barniol and Zavala analyzed students' performance in MWCS, described the main difficulties that students face, compared the result with the previous results of the original design in PhsPort, and elaborated on the main difficulties taking into consideration inappropriate conceptions. They also investigated students' primary difficulties with the MWCS topics and elaborated on these difficulties in terms of students' inappropriate responses.

The topics examined in the MWCS assessment test were mainly propagation, superposition, reflection and standing waves. Research done on these topics include studies by (Barniol & Zavala, 2017; Kennedy & de Bruyn, 2011; Kryjevskaia et al., 2012; Pejuan et al., 2012; Zeng et al., 2014). The literature considered the concepts of mechanical waves in the topics and the relationship with students' understanding of the topics. Barniol and Zavala (2016) analysed students' performance on MWCS as well and described the main difficulties that students encountered. They compared their results with the results of the main designer of the tests and elaborated on the main difficulties in terms of students' inappropriate conceptions. All the previous research discussed in the different literature discussed earlier was conducted using undergraduate engineering and physics major students in the university as the subjects in non-African countries, none of the studies considered preservice teachers (PST) or novice PST as the subject, and in an African country. Olaniyan and Govender (2020) investigated university students' conceptions of the propagation of sound using a section of MWCS2. The study came to the conclusion that Ugandan university students have varieties of alternative conceptions and conceptual schema compared with the scientific conception of sound waves.

This specific research assessed the novice preservice physics teachers' conceptual understanding of mechanical waves in Uganda by taking a closer look at their performance using qualitative and quantitative approaches. The quantitative analysis of novice preservice physics teachers' responses to the

MWCS2 assesses the correct options given by the preservice teachers by considering how their responses to the multiple choice were distributed using descriptive analysis. It further sought how effective questions are in seeking novice preservice teachers' conceptual knowledge and the possible patterns of the distribution of their options. The qualitative approach took a closer look at why the novice preservice teachers answered the questions in the manner of which they were, by considering what is the conceptual understanding required by the MWCS2 and what the wrong conceptions are. It also looks into the novice preservice teachers' organization of thoughts and thinking patterns in the framework of the conceptual schema (Kuo, Hull, Gupta, & Elby, 2013) and knowledge in pieces (Disessa, 1988). The study sought to explain the possible reasons for students' wrong conceptions or misconceptions by looking deeply into the required conceptual understanding from the textbooks and the literature before possible conclusions were made. The study sought to answer the following research question; what are the novice preservice teachers' conceptual understanding of mechanical waves and how are they classified into scientific conceptions, alternative conceptions, and misconceptions?

II. THEORETICAL FRAMEWORK

Research in physics education had focused on students' conceptions and the means to diagnose and correct them. Many of these studies identified that students have difficulties in conceptual understanding (Barth-Cohen & Wittmann, 2016; Bolat & Kocacan, 2018; Eshach & Schwartz, 2006; Lee, 2007; M. Wittmann, Steinberg, & Redish, 2003). Though students may be able to solve quantitative physics problems, they cannot explain simple conceptual questions and bring out conceptual understandings of major concepts which are associated with the topics. The phenomenon of student thinking patterns, conceptual schema, and bringing pieces of knowledge into problem interpretation and conceptual understanding are the framework for which research has identified as responsible for this challenge. In this study, the novice preservice teachers' conceptual understanding of mechanical waves was assessed by taking a leave from Disessa theory of knowledge in pieces. Disessa (1988) stated that intuitive physics consists of a rather large number of fragments rather than one or even any small number of integrated structures one might call theories. He referred to these fragments as phenomenological primitives (p-prime). The framework for the construction of knowledge can be understood as abstractions from common experiences, piece by piece that is taken as relatively primitive in the sense that they generally need no explanation, they simply happen. Intuitive physics ideas could also be referred to as conceptual schema, meaning ideas that can be but does not have to be represented mathematically in form of an equation or expression. By "intuitive" ideas, we mean ideas that are informal knowledge drawn from every day (non-academic), ideas that make quick and immediate sense and that do not seem to require further explanation. One example of such a conceptual schema is the idea that a whole consists of many parts (Kuo et al., 2013).

A conceptual schema is an intuitive idea used in everyday, non-scientific reasoning, not a formal scientific concept. A student's understanding of a formal scientific concept (such as mechanical wave) can draw upon these intuitive conceptual schemata (such as a whole consisting of many parts), which plays a role in students' reasoning about other subjects. Using the conceptual schema corresponding to Parts-of-a-Whole, with the idea of symbolic form in solving physics problems. A symbolic form is a cognitive element that blends a symbol template with a conceptual schema, such that the equation is interpreted as expressing meaning corresponding to the conceptual schema. Kuo et al. (2013) discovered that when a symbolic form is used, the reasoning is neither purely formal mathematical nor purely conceptual; it is blended into a unified way of thinking that leverages both intuitive conceptual reasoning and mathematical formalism. Students productively used symbolic forms in two ways, one was to produce novel equations from an intuitive conceptual understanding of a physical situation. The other was to use symbolic forms to interpret mathematical equations in terms of a physical scenario, using functional relations expressed by the equation (Rodriguez et al., 2020; Hestenes, 2010; Tuminaro & Redish, 2007). Disessa's theory of knowledge in pieces viewed intuitive knowledge in physics as posing a fundamental educational problem. The most fundamental problem is the simple fact that students come to physics classes with no theory at all but instead are used to dealing with the world on a catch-as-catch-can, where it is quite fair to change tactics whenever the problem is minutely varied. Two ways in which physics students use a conceptual schema in symbolic forms correspond to steps involving conceptual reasoning as described by problem-solving literature. These are translating a conceptual understanding of a physical scenario into a mathematical equation at the start of the problem and giving a physical interpretation of a mathematical solution at the end (Disessa, 1988). Chi, Feltovich, and Glaser (1981) conducted an investigation of the categorization of representation of physics problems by experts and novices. Quality of problem representation influences the ease with which both experts and novices solve problems and interpreted questions, however, the experts' representation is superior because it contains a great deal of qualitative in-depth knowledge with detailed application of principles and theories while the novices' demonstrated shallow or surface knowledge of the concept without application of principles and theories which the concepts are based. Further, the studies of Chi et al. (1981) and Disessa (1988) also noted that the pattern through which knowledge is constructed otherwise known as conceptual schema varies from experts to novices; experts associated their principles with procedural knowledge about their applicability while novices casually relate the principle with the concept and opted for an alternative conception. The studies examined in this theoretical framework considered differences in the approach of experts and novices in conceptual understanding with the use of knowledge in pieces and conceptual schema, this phenomenological way of reasoning by the novice preservice teachers is what was examined in this paper to assess their conceptual understanding of mechanical waves.

III. METHODOLOGY

This research is a case study mixed method research using year one preservice teachers of a private university in Kampala, Uganda. The department of science education has over 100 preservice teachers in science education which include Mathematics, Physics, Chemistry, and Biology, out of which 30 are physics students in year 1, semester 2 registered at this university. Mechanical waves, sound, and optics are major topics in the core courses which are the basic requirement for their studies and professional training as these appear in the high school physics curriculum in Uganda. These topics run through all their three years (six semesters) program, they are prerequisites for higher-level courses like classical mechanics and optic fiber communication. Data were collected using Mechanical Waves Conceptual Survey Two (MWCS2), which is an improved version of MWCS1, a standardized physics assessment test developed by PhysPort. MWCS1 was used in the previous studies of Barniol and Zavala (2016) and Olaniyan and Govender (2020). The research lasted over a period of twelve weeks, the preservice teachers were taught the concepts examined in the ten sub-topics covered in the MWCS2 for eleven weeks after which the test was administered in the twelfth week. Twenty-seven students out of thirty students participated in the research as it was voluntary.

The Instrument (Mechanical Waves Conceptual Survey 2)

Mechanical Waves Conceptual Survey 2 **(**MWCS2) is a standardized assessment developed by Barniol and Zavala (2016) in Mexico after a critical review of MWSC1 which was developed for a period of time after concerted efforts of validation and reliability and acknowledged by AAPT and the PhysPort website. The questions focused on major topics on reflection, propagation, superposition, and standing wave. MWSC2 consists of twenty-two multiple-choice questions each having five options (A-E), one correct answer (the key), and four wrong answers (the distractors). The distractors are alternative conceptions, wrong conceptions, or misconceptions which are critically examined in each question, option by option alongside the key by making reference to other literature to assess preservice teachers' conceptual knowledge of mechanical waves. Table 1 presents the description of MWSC2 by topics, subtopics, and conceptual understanding evaluated.

Table 1:

Main Topic	Sub-topic	Question	Conceptual Understanding Evaluated
Propagation	Sound variables	1	Interpretation of amplitude and frequency
	Speed of sound waves	2	Speed in air independent of frequency
		3	Speed in air independent of frequency and amplitude
	Speed of waves on strings	4	Speed is proportional to tension and independent of the changes in hand movement
		5	Speed proportional to density and tension
	Displacement of medium in sound waves	6	Longitudinal oscillation of air particles perturbed
		7	Increase of frequency: Oscillation is faster
		8	Increase of amplitude: Oscillation is wider
Superposition	Superposition-Construction	9	Superposition of two waves during overlap
		10	Superposition of two waves after the overlap
	Superposition-Destruction	11	Superposition of two waves during the overlap
		12	Superposition of two waves after the overlap
Reflection	Reflection-Fixed end	13	Complete reflection of an asymmetric pulse
		14	Complete reflection of an asymmetric pulse
	Reflection-Free end	15	Half reflection of a symmetric pulse
		16	Half reflection of an asymmetric pulse
Standing waves	Transverse standing waves in strings	17	Increasing frequency in the string, the wavelength of the new standing wave decreases
		18	Increasing tension in the string, the wavelength of the new standing wave increases
		19	Increasing density of the string, the wavelength of the new standing wave decreases
	Longitudinal standing waves in sound	20	Pattern of displacement of air molecules inside a cylinder open at one end in the first harmonic
		21	Pattern of displacement of air molecules inside a cylinder open at both ends in the first harmonic (new position)
		22	The pitch generated by air blown across the top end of a bottle will be higher when it contains a greater volume of water

Data Analysis of Students' Performance in MWSC2 Propagation (Question 1-8)

Question 1 deals with novice preservice teachers' understanding of the relationship between frequency and amplitude as they affect the pitch of the sound. Also, NPST are expected to relate with amplitude and volume as the same in this concept. The correct answer is option B which was chosen by 4 NPPT (14.81%), the amplitude is the same while the frequencies are different. They are expected to understand that amplitude is the same as the volume of sound and that pitch is proportional to frequency. The alternative conceptions are options A (12 NPPT -44.44%), D, 5 NPPT (18.51%), and option E, 6 students (22.22%) which showed a wrong pitch-frequency relationship with correct amplitude and vice versa. The qualitative analysis reveals two incorrect models and these incorrect models are A and E. Analyzing why NPPT chose the more incorrect model which is option A, amplitudes are the same while frequencies are different. NPPT did not understand that the same volume implies the same amplitude with sound. Their misconception was probably the reason for the incorrect model. The major concept is the volume of sound linked to loudness and loudness linked to amplitude, the pitch is proportional to frequency, and if the volume of sound is the same then the amplitude does not change. NPPT conceptual understanding was found to be related to DiSessa theory of knowledge in piece and organization of physics knowledge.

In questions 2 and 3 the main concept evaluated is 'factors affecting the speed of sound in the air'. Question 2 attempted to find out novice preservice teachers' conceptual understanding when the velocity of two sound waves at different frequencies and the same amplitude (volume) are compared. The correct option is A, chosen by 6 NPPT (22.22%) while the incorrect options and alternative conceptions are option B, 13 NPPT (46.15%), and D, 7 NPPT (25.92%). The wrong concept is that as the speed increases the frequency increases. Option B is a major distractor because of NPPT wrong assumption about the relationship between f, v λ. From the relation V= fλ, the speed of sound does not depend on frequency as an increase in wave frequency produces a decrease in wavelength while the wave speed remains constant.

In question 3, the NPPT is to compare the velocities of two sound waves in the air with different amplitudes but the same frequencies. The correct answer is D, 4 NPPT (14.81%) while the alternative conceptions are options C, 6 NPPT (22.22%) and E, 11 NPPT (40.47%). Option E is a major distractor and a wrong conceptual understanding that the higher the amplitude the higher the speed of the wave. Amplitude does not affect the wave speed at which the wave travels. Conceptual knowledge in questions 2 and 3 is that the *speed of a wave is only affected or altered by alterations in the properties of the medium through which it travels*. In this case, the medium is air and properties include temperature, pressure, and density. In other words; the speed of sound in air is independent of frequency and amplitude but is dependent on the properties of air (temperature, pressure, and density) and not on characteristics of sound (quality, pitch, and loudness). In questions 2 and 3 NPPT made use of mathematics schema and knowledge in pieces to provide answers to the questions. They do not have factual knowledge, mental or context understanding of factors affecting the speed of sound in the air but rather are made of mathematical knowledge.

Table 2A: Showing the distribution of Answers in Percentages

Main Topic	Sub-topic	Question	Option (%)				
			A	B	C	D	E
Propagation	Sound variables	1	44.44	**14.81**	3.70	18.51	22.22
	Speed of sound waves	2	**22.22**	48.14	3.70	25.92	0
		3	11.11	11.11	22.22	**14.81**	40.74
	Speed of waves on strings	4	18.51	18.51	0	**51.85**	14.81
		5	**48.81**	22.22	11.11	7.40	11.11
	Displacement of medium in sound waves	6	0	**51.85**	0	29.62	18.51
		7	33.33	**33.33**	0	7.40	25.92
		8	**18.51**	14.81	7.40	40.74	18.51

Questions 4 and 5 examined factors affecting the speed of the wave in the string and the effects of density and tension on the wave produced. Question 4 attempted to know NPPT understanding of the relationship between the speed of wave produced when the pulse that takes less time is produced. Option D (51.85%) is the correct answer and the right conceptual understanding, the speed of sound in string depends on the tension and not by increasing the flick's up and down movement. In other words, for the pulse to take less time, there must be an increase in tension produced not an increase in frequency. The incorrect answers and wrong conceptual understanding are options A and B (18.51%) each. Question 5 assesses the relationship between the speed of the sound wave in string and density. For the pulse to travel in less time, a lighter string is required under the same tension because the velocity of sound production in string increases as the density decreases. 13 NPPT (48.15%) got the answer correctly while option B (22.22%) and options C and E with 3 NPPT (11.11%) each are the alternative and wrong conceptions. The conceptual understanding evaluated in questions 4 and 5 is that the speed of the sound wave in the string is independent of frequency but it depends on the tension and density of the string. An increase in tension produces an increase in the speed of the sound wave produced and a decrease in the density of the string by using a string of lighter thickness than the speed of sound in the string increases. NPPT conceptual understanding was found to be related to Disessa theory of knowledge in piece and organization of physics knowledge. They did not have a full grasp of the theoretical knowledge involved in these concepts, they only pick some knowledge at the surface no deep thought or in-depth logical reasoning to substantiate their responses.

Questions 6, 7, and 8 addressed the concept of displacement of the particle when sound is produced by a loudspeaker. In question 6 NPPT were to identify the movement of the dust particle in front of a loudspeaker when the speaker is turned on and plays a loud tone at a constant pitch. Option D is the correct answer chosen by 8 students (29.63%) while the alternative conceptions are option B, (51.85%) and option E, (18.52%). In the correct answer, NPPT were able to answer the question by bringing out the conceptual understanding that the dust particle will move away from the speaker. 51.85% went for option B which is a wrong conception, an indication of a poor understanding of the concept, and a wrong conceptual schema in appropriating logical reason of a displaced particle when sound is produced by a loudspeaker. Question 7, inquired to know what happens to the motion of the dust particle when the pitch of a sound is increased and the volume is kept constant. Option D is the correct answer (7.41%) while options A, (33.33%), option C (33.33%), and option E, 7 NPPT (25.93%) are the alternative conceptions. In the correct answer, the NPPT identified that the particle will move faster but in an up-and-down movement in the same position. The misconception or wrong conception in options A, C, and E is NPPT lack of understanding of the implication of the word further or move away which is an indication of a lack of depth in the concept and language of interpretation. Similarly, question 8, examined what happens to the motion of the dust when the volume is increased but the pitch is the same. Option A, (18.52%) is the correct answer. The alternative conception is option D, (40,47%), option E, (18.52%), and option B, (14.81%). In the correct answer, NPPT were able to understand that with increasing volume the particles gain more energy and move further away than before. The general concept evaluated in questions 7 and 8 is, a high-pitch sound corresponds to a high-frequency sound wave and a low-pitch sound corresponds to a low-frequency sound wave. When pitch increases, the frequency of oscillation is faster, while an increase in volume (amplitude) produces a wider oscillation when the pitch is kept constant.

Superposition Principle (Question 9-12)

Questions 9 and 10 are the constructive superposition of two waves at the moment of overlap and after overlap, students were expected to choose from the correct diagrams. In question 9, (7.4%) got question 9 correctly which is option D. They were unable to interpret correctly the physics of constructive superposition of two waves at the moment of overlap, that is the addition of displacements due to each wave pulse on a point-by-point basis. The wrong options and common misconceptions are A, B, and C with 25.92%, 33.33%, and 25.92% respectively. These alternative conceptions do not indicate any superposition. In question 10 options A, (40.74%), they were able to identify the two waves that have passed through one another and retained their shape from the diagram which shows the constructive superposition of two waves after overlap. The alternative conceptions were options B and C which represents 22% each.

Table 2B:

Main Topic	Sub-topic	Question	Option (%)				
			A	**B**	**C**	**D**	**E**
Superposition	Superposition-Construction	9	25.92	33.33	25.92	**7.40**	3.70
		10	**40.74**	22.22	22.22	7.40	7.40
	Superposition-Destruction	11	11.11	44.44	**25.93**	11.11	7.40
		12	**18.51**	48.15	25.93	3.70	3,70

Questions 11 and 12 deal with the destructive superposition of two waves at the moments of overlap and after overlap. In question 11 option C (25.92%) answered the question correctly by choosing a sketch that shows the addition of displacements due to each wave pulse on a point-by-point basis. Option B (44.44%)is the alternative conception which indicates that most of the NPPT do not really understand the concept. In question 12 option A, (18.51%) is the correct answer, NPPT were able to identify the diagram that corresponds to the shape of the resultant pulse after 5 secs. They were able to identify that the waves passed through one another and retained their shapes. The alternative conceptions are options B (48.15%) and C (25.93%).

In questions 9, 10, and 12 the incorrect models were selected by more students than the correct models. There are more alternative conceptions than correct options. This indicates that NPPT's conceptual understanding of the principle of superposition of two waves during and after overlap is poor. Students cannot relate the movement of pulses A and B within a given distance in a specific time with the nature of the resultant wave formed when they are superimposed. A confused memory and understanding of the principle of superposition. Confused understanding of, and lack of proper interpretation of destructive and constructive interference or superposition of wave motion. This may be because the students are not familiar with practical applications related to concepts as projected in the diagrams.

Reflection (Question 13-16)

This section deals with the reflection of the wave in a symmetric pulse and an asymmetric pulse. In questions 13 and 14 NPPT are expected to choose the correct wave motion in an asymmetric pulse. Five NPPT (18.51%) chose options D and B the correct answers to questions 13 and 14 respectively. The mechanical wave concept in these questions is that the students are expected to identify the sketch that shows a pulse on the opposite side of the string and vertically inverted (question 13), and a pulse on the same side of the string but with a vertical inversion (question 14) since the right tail will be reflected as the left tail of the new pulse. The alternative conceptions in question 13 are options A (18.51%), C (29.62%), and E (22.22%) while the alternative conceptions in question 14 are options D (33.33%) and E (25.92%).

Table 2C:

Main Topic	Sub-topic	Question	Option (%)				
			A	**B**	**C**	**D**	**E**
Reflection	Reflection-Fixed end	13	18.52	11.11	29.63	**18.52**	22.22
		14	11.11	**18.52**	11.11	33.33	25.93
	Reflection-Free end	15	25.93	**14.81**	25.93	14.81	18.52
		16	**18.52**	11,11	29.63	0	37.04

Questions 15 and 16 deal with the reflection of the wave in a symmetric pulse. Four NPPT (14.81%) and five NPPT (18.51%) chose the correct answers to questions 15 and 16 respectively. They were able to understand the concept by identifying the string in its original form that shows half reflected pulse that cancels the half pulse that has not been reflected. The wrong conceptions are options A (25.92%), C (25.92%), and E (18.51%) in question 15, and options C (25,62%) and E (37.03%) in question 16. The NPPT are expected to identify half-reflection pulse on a free-end string and fixed-end string. It is expected that the NPPT imagine that the spring extends past the fixed end and that a pulse is sent along the imaginary portion toward the fixed end. While the end of the spring remains fixed students are expected to choose the shape, orientation, and location of the imagined pulse so that as it passes the incident pulse. In this case, the reflected and imagined pulses have the same shape and orientation. The most frequent error was choosing a reflected pulse on the correct side of the string but with no vertical inversion or incomplete reflection. Students lack understanding of the conditions stated above hence most of them chose the incorrect answers in questions 13-16. The option chosen was more random selections by guessing. No correct model can be suggested for the selection. The reason could be that the students do not understand this concept at all.

Standing Wave (Question 17-22)

Concepts evaluated in this session include transverse waves in string and longitudinal waves in sound. Questions 17-19 deal with finding students' conceptual understanding of standing waves produces with a fixed-length string, one end of which is attached to a vibrator, the other end of which is placed on a pulley and hung with a mass. The questions varied the frequency mas and thickness of the rope and required students to identify the correct statement from option A to E in each question. In question 17, 15 students (55.56%) chose option D the correct while the alternative conception was option E which was chosen by 6 students (22.22%). In question 18, 12 students (44.44%) chose option A while the close alternative conception is option C chosen by 7 students (25.93%), other alternative conceptions were options D, 3 students (11.11%) and E, 3 students (11.11%). In question 19, 3 students (11.11%) got the answer correctly, which is option D while alternative conceptions were option A, 7 students (25.93%), option B, 5 students (18.52%), and option C, 9 students (33.33%).

Table 2D:

Main Topic	Sub-topic	Question	Option (%)				
			A	**B**	**C**	**D**	**E**
Standing Waves	Transverse standing waves in strings	17	11.11	7.41	3.70	**55.56**	22.22
		18	**44.44**	7,40	25.93	11.11	11.11
		19	25.93	18.52	**33.33**	11.11	11.11
	Longitudinal standing waves in sound	20	11.11	14.81	**66.67**	0	7.40
		21	3.70	0	0	7.40	**81.48**
		22	**11.11**	22.22	3.70	11.11	51.85

The conceptual understanding examined in these questions is to determine how the frequency (f), tension (τ), and density (ρ) affect wavelength (λ) in the string. In question 17, the frequency (f) is doubled while every other factors including wave speed (v) remains the same, and wavelength (λ) decreases because the wavelength is inversely proportional to frequency $\lambda = \frac{V}{f}$(an increase in the frequency of vibration of the string produces a decrease in wavelength). Most students understand this relationship well. The alternative conceptions which served as distracters, options, E A and B presented the wrong relationship between frequency and wavelength. The total of 12 students that chose these appear to be guessing or do not understand the concept at all. In question 18, the mass that hung on the string increased, which resulted in an increase in tension on the string. An increase in tension produces an increase in wavelength because the speed of the wave also increases. It can also be expressed as tension (τ) is directly proportional to wavelength (λ). The distracter B, chosen by 2 students, also stated that an increase in tension produces an increase in wavelength but added that it is harder to get the string to vibrate. This is not scientifically correct. The distracter C, chosen by 7 students (25.93%) is the alternative conception which began by stating that wavelength decreases. Seven students chose this alternative conception as an indication that the students do not really have a correct understanding of the concept. In question 19, a thicker rope which indicates more mass (increase in density) was used while other factors remained the same. The students were expected to identify correct statement out of the options A-E. Option D the correct option stated that the wavelength decreases because as rope becomes heavier (denser), the amount of energy flowing in the wave decreases. This shows the correct relationship between density (ρ) and wavelength (λ), while the alternative conceptions, options A, B, and C are distracters. They are the wrong conception popularly chosen by most students.

Questions 20-22 deal with a longitudinal standing wave in sound (vibrating air column). Questions 20 and 21 have 18 students (66.67%), option C and 22 students (81.48%), and option E who got the right option respectively. Question 20 is on vibrating air column open at one end while question 21 is on vibrating air column open at both ends. The outcome of these two questions indicates that students could relate to these diagrams very well conceptually. They have a good grasp of what the conceptual knowledge in these questions is all about. Question 22 is a theoretical application of question 20 seeking to find the relationship between the frequency of sound (first and second harmonics), the pitch, and the wavelength produced when the air is blown into a bottle that is one-third full and half full. 3 students (11.11%) got the answer correctly while the wrong conceptions options B and E were chosen by 6 and 14 students respectively. These are the alternative conceptions that the reasons for the pitch of the second sound to be lower or higher as the case may be because the molecules have less space to vibrate.

The alternative conceptions are options A (13%) and B (41%). The alternative conceptions in question 22 are due to students' inability to practically relate the length of the vibrating air column with the wavelength. When the wavelength is shorter it produces a higher pitch. Though students appear to understand the concept of vibrating air column more in questions 20 and 21 than in question 22. The students seem to be able to relate to diagrams well in explaining the first harmonics in open and closed pipes but they could not apply the same knowledge in interpreting the question and applying it in question 22.

It could be concluded that students lack the ability to interpret questions that are presented imaginarily in question 22 into concrete interpretation and understanding as in questions 20 and 21. Question 22 is a clear indication of poor conceptual knowledge of the vibrating air columns especially when it does not involve the description through the use of diagrams is not involved. The students' conceptual understanding.

Further Discussion on Preservice Teachers' Conceptual Understanding of Mechanical Wave

The results of the responses of the novice preservice physics teachers to the MWCS2 from both the qualitative and quantitative analysis showed that the conceptual understanding is very poor. This reflects in the findings from their response pattern in the quantitative analysis and interpretive qualitative analysis of their answers to MWCS2 questions by question. Further discussions on their responses and possible reasons for their conceptual understanding based on one on one interaction with the students in different interactive sessions with the preservice teachers were discussed by sub-topics.

Sound variable: Confusion, memory problem, and understanding problems due to pedagogy, depending on what was done during teaching. There is the possibility that the relationship between frequency and amplitude was not properly reinforced and emphasized. This result is in agreement with Menchen and Thompson (2004); Barniol and Zavala (2017); Pejuan et al. (2012) Olaniyan and Govender (2020).

The speed of sound waves: This sub-topic includes questions 3 and 4. The reasons for poor conceptual understanding include; Confusion, memory problem, and understanding problems due to pedagogy, on the relationship between v, f & depending on what was done during teaching. Poor conceptual understanding of change in frequency and how it affects sound heard by the human. There is a possibility that It was not properly reinforced or emphasized. Lack of understanding of the relationship between loudness, pitch, and speed travel by a wave. The misconception about the increase in volume (loudness or amplitude) and speed of the wave. Amplitude does not affect the speed or velocity of a wave. These findings are in line with (Barniol & Zavala, 2017; Kennedy & de Bruyn, 2011; Pejuan et al., 2012) who found that students consider sound speed as dependent on frequency based on the reasoning that suggests object-like properties of sound.

The speed of waves on strings: In this sub-topic, about an average of the novice preservice physics teachers have a conceptual understanding of the relationship between speed and tension, and speed and density. The major misconceptions are options A and B in question 4, and B in question 5, preservice physics teachers' misconception and alternative conception stems from their confused understanding of the effect of how fast the string is flicked, the height of the flick, and thickness of the string with on pulse produced. This is in agreement with Bolat and Kocacan (2018) who mentioned that students associated flicking the string faster and the height of the flick with the pulse produced.

Displacement of the medium in sound waves: The concept examined is a student of understanding of longitudinal and transverse waves and how pitch and frequency affect sound produced. Preservice teachers' responses showed a lack of understanding of what happens when an air particle is perturbed. The general misconception is up and down movement along a line (transverse) but the correct conceptual knowledge is forward and backward along a line (longitudinal). This is in agreement with M. Wittmann et al. (2003); Barniol and Zavala (2016) and Olaniyan and Govender (2020). Another alternative conception and misconception emerged from an attempt by the preservice teachers to interpret the question by finding the relationship between pitch and frequency. A high-pitch sound corresponds to a high-frequency sound wave and a low-pitch sound corresponds to a low-frequency sound wave. When pitch increases, the frequency of oscillation is faster, while an increase in volume (amplitude) produces a wider oscillation when the pitch is kept constant.

Superposition (Construction and Destruction in the moment of overlap and after overlap): The novice preservice physics teachers demonstrated a lack of understanding of constructive interference of waves by using a single point on the wave when they described the construction and destruction in the moment of overlaps. Also, at the moment after overlap, they described the superposition of waves in terms of the collision of waves. These are common misconceptions and alternative conceptions which are identified in the previous works of Barniol and Zavala (2016); Bolat and Kocacan (2018). These also indicate that Students' conceptual understanding of the principle of superposition of two waves during and after overlap is poor. Students cannot relate the movement of pulses A and B within a given distance in a specific time with the nature of the resultant wave formed when they are superimposed. A confused memory and understanding of the principle of superposition. Confused understanding of, and lack of proper interpretation of destructive and constructive interference of wave motion. This may be because the students are not familiar with practical applications related to concepts as projected in the diagrams.

Reflection (Fixed and Free ends): Complete reflection of an asymmetric and a symmetric pulse, and Half reflection of an asymmetric and a symmetric pulse were the main concept examined in this sub-topic. The options chosen by preservice teachers are a strong indication of guesswork and a gross lack of conceptual understanding in this sub-topic. In the previous work of Barniol and Zavala (2016); and Kryjevskaia et al. (2011), they found that students think of a pulse reflected on the right side of the string and tend to use simple rule-based approaches instead of applying reflection models based on the superposition principle. In this specific study, the preservice physics teachers' responses to the questions in this sub-topic show a consistent pattern of low scores and low concentration which is an indication that the conceptual understanding of the preservice teachers on reflection of a symmetric and an asymmetric pulse is very poor.

Transverse standing waves in strings: A string with 2 fixed ends can produce different standing waves. The lowest frequency standing wave that can be produced has a wavelength λ where $\lambda = 2l$ (l $is\ the\ length\ of\ the\ string$. This is related to the frequency f of oscillation by the wave equation $v = f\lambda$. Therefore $f = \frac{v}{\lambda} = \frac{v}{2l}$ F is inversely proportional to the length of the string, the shorter the string, the higher the note. The frequency also depends on the tension and the mass per unit length of the string as they affect the speed of transverse waves traveling along the string. The greater, the tension, the greater the speed, and the heavier the string the lower the speed. The common error and general misconception of the preservice teachers is the inability to correctly interpret the relationship between frequency, tension, and density. This is in agreement with the findings of Barniol and Zavala (2016), and Ringo and Mulvia (2022), they observed that the most common error was by increasing the frequency in the string which was reported as a justification error. Also, the most common error in increasing the tension in the string or increasing the density of the string is incorrectly predicting the opposite of the correct answer, but remarkably, selecting the correct justification.

Longitudinal standing waves in sound: the preservice teachers performed reasonably well in this sub-topic, it could be observed that almost all got the answer correctly in questions 20 and 21, and they do not have difficulties describing the wavelength of the harmonics in open and closed tubes while the situation is not the same in question 22. Question 22 is a theoretical approach to the two other questions in this sub-topic. The reason for this was found to be inappropriate conception and inability to relate what is presented abstractly in question 22 with what is presented diagrammatically in questions 20 and 21. This is in agreement with the research efforts of Bezen and Bayrak (2020); Barniol and Zavala (2016), and Zeng et al. (2014) which confirmed the inappropriate conception and most frequent error is confusing displacement nodes with pressure nodes and displacement antinodes with pressure antinodes.

IV. CONCLUSION AND RECOMMENDATION

The study concludes that the novice preserve physics teachers possess varieties of alternative conceptions and misconceptions in mechanical waves as compared with the scientific conceptual understanding. The alternative conceptions and misconceptions are due to; confusion, memory problem, poor pedagogy, poor mathematics knowledge, inability to establish relationships between concepts, guesswork, and lack of ability to relate concepts with daily life experiences. It was also observed that novice preservice teachers possess various pieces of knowledge and conceptual schema as postulated by Disessa (1988). The study recommends a need for a more engaging, student-friendly, and learners-centered pedagogy for effective teaching and learning amongst novice preservice teachers.

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