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WAVES: AN INTEGRATED APPROACH WITH REAL WORLD APPLICATIONS

By

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ABSTRACT

WAVES: AN INTEGRATED APPROACH WITH REAL WORLD APPLICATIONS

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Sandra L. Brough-Gresh

Students need to understand the use and application of waves and their interactions in their everyday lives. This nine-week unit was designed to include more applications of wave properties through laboratory exercises, portfolio assessments, writing exercises, and classroom discussion utilizing the natural inquisitiveness of ninth graders. The unit consisted of lecture, discussion, student and teacher designed laboratory exercises, projects, and performance activities. Classroom discussions indicated that the students enjoyed learning about wave concepts outside the classroom. Post-surveys showed that most students felt that they had a good solid understanding of the objectives at the conclusion of the unit. Comparison of pre- and posttest responses illustrated that students gained a significant amount of practical knowledge about waves as a result of this unit.

ACKNOWLEDGEMENTS

I would like to show my deepest appreciation to the following people for all of their personal and professional support:

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INTRODUCTION

Statement of Problem and Rationale for Study

I have taught science for nine years and I still consider myself a rookie. I am constantly looking for new ways to bring science 'home' to my students. The Universal Science and Technology course I have taught for the past six years allows me the flexibility to continually modify the style and structure of the course as long as the objectives set by the course curriculum are met. I teach one semester of this course for ninth grade students, and then teach this same course again second semester to a new set of students. This semester addresses MEAP objectives focusing on the basic concepts in laboratory procedure, chemistry, physics, and earth science. I discovered that even though students were learning science they didn't see the correlations between the disciplines or the connections of science outside the classroom walls.

This new unit uses sound and light to teach different characteristics of waves such as propagation, interaction, and their use in technology. Primary and Secondary seismic waves were used to show comparisons and contradictions to light and sound waves, and to check for understanding of the material. To not only make learning more relevant to my students and to help them see how the sciences overlap and can be applied to everyday life, I decided to redesign the waves portion of the course. The objectives of this new waves unit (Appendix A-I) were modeled after specific MEGOSE objectives (Appendix A-II). By utilizing a thematic approach, a central theme was chosen and then that theme was built upon through examples from different science disciplines. In order to make the learning meaningful to the students authentic assessment was incorporated. It is my belief that the students would begin to see, understand, and utilize the connections and uses for the science that they are learning as a result of these teaching techniques. The students need to make these connections themselves for the learning to be meaningful and long lasting (Hartley, 1999).

The class has always been taught with a variety of tools to keep the students on task and active in the learning process. A range of learning activities and flexible management of the activities provides the students with responsibility for their own learning and development (Postlethwaite, 1993). When students feel that they have input into the structure of the class they are more willing to take an active role in the learning process. Learning is an active, not passive process that enables the learners to maximize their opportunity for understanding (White, 1988).

Laboratory exercises were the main focus of the class. Investigations allow students to develop questions and demonstrate their understanding by gathering and analyzing information (Lang, 1999). The style of the laboratory experience varies depending on the goal of the experiment: to introduce the topic, to develop connections or relationships, or to draw conclusions about the topic. Lecture, small and large group discussion, writing activities, and long-range projects round out the ways in which the students are engaged in science. Activities for group learning are successful when based on collaboration and not simply exercises in "doing" (National Science Education Standards, 1996).

I believe science is for all students and that learning is an active process. Everyone is capable of learning at some level. If students are taught how to learn and are given an avenue to want to learn then who knows how much they can learn. Skilled teachers guide their students to understand the purposes for their own learning (National Science Education Standards, 1996). As teachers our goal is to develop an environment for our students to help them achieve their fullest potential. When teachers treat students as serious learners they come to understand and apply good teaching practices (National Science Education Standards, 1996). Every student has to be given the opportunity to learn. As teachers our focus is to provide such an environment, physically and emotionally. Teachers need to be ever mindful that the pace, structure, and level of instruction will vary for each student and for each topic (Texley, 1998).

Our school has been and is still undergoing major renovations. I taught science in a math room during the 2000-2001 year. This room was wired for electricity around the perimeter, but the only available water was the drinking fountain down the hall and the custodial sink around the corner. We had to "make do" with the custodial sink for the activities when water will be needed.

With these parameters in mind, I decided to focus my research on the physics, specifically waves, portion of the course and leave the chemistry topics for later in the semester when we were to be back into our new science rooms. I knew that even though I intended to redevelop my entire curriculum to incorporate thematic and authentic styles, I needed to focus on the one that could be most easily implemented…the waves unit. Seven weeks were set aside for the implementation of the unit. The last two weeks of the marking period were used to allow extra time if needed to effectively implement the material. An effective unit should allow, from time to time, groups or individuals more time to engage in particular tasks when necessary (Bentley, 1992).

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Students often have difficulty seeing the whole picture. They want to learn what's going to be on the test and that's it. This unit teaches the students that the properties of sound, light and earthquake waves are not separate entities but are all waves. This unit also encompasses other academic areas: writing, mathematics, geography, music, and history. The growth of interdisciplinary techniques to facilitate learning can have a powerful effect on the students involved (Bransford, 1999).

Scientific Background- The Physics of Waves

Waves transmit energy through matter or space. They are limited by where they can travel. Mechanical waves are produced by vibrating objects and can only travel in matter. These are sound, water, and seismic waves. Electromagnetic waves are produced by moving electrically charged particles and can travel in matter or space. These are light, radio, x-rays, gamma rays, microwaves, ultraviolet light, and infrared light.

All waves are a means by which energy travels. All waves have some common characteristics such as wavelength, frequency, amplitude, and speed. The type of energy and where and how that energy is transferred varies among light, sound, seismic or water waves. Light is an electromagnetic wave that propagates transversely. Sound, seismic, and water waves are all mechanical in nature but their propagation varies. Sound waves are longitudinal, seismic waves can be transverse, as in the secondary seismic waves, or longitudinal, as in primary seismic waves. Water waves have characteristics of both transverse and longitudinal waves. It is important to make the distinction between transverse and longitudinal waves. Many students have a superficial understanding of how sound travels. Since sound cannot be seen their perception of sound is often misdirected (Hartley, 1999). It needs to be made very clear to the students that occ

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occasionally longitudinal waves, such as sound waves, are represented as transverse waves, such as when displayed on an oscilloscope or heard through equalizers on stereos.

Waves are also described by their propagation or how they travel. Longitudinal or compressional waves are produced when the density of molecules is compressed and rarefied. The particles in the wave move parallel to the direction the energy is traveling. Sound waves and primary or P- seismic waves are examples of compressional waves. Transverse waves are waves that cause the particles in the medium to vibrate perpendicular to the direction the energy is traveling. In terms of light waves there is no medium. Light waves and secondary or S- seismic waves are examples of transverse waves.

The amplitude of a wave, the height of a sinusoidal wave, reflects the energy put into a wave. For sound that is the volume, for light that is the intensity (brightness), for earthquakes that is the vibrations or shaking, and so on. The frequency of a wave is the number of oscillations or waves that occur per second. The length of one complete oscillation, or wave, is known as the wavelength.

The energy that produces a wave is carried by that wave. In the case of sound, the wave travels through the air or medium of propagation as vibrations. These vibrations require matter to travel and are thus classified as mechanical in nature. When this mechanical energy reaches the auricle, or outer ear, it is funneled into the ear canal. These vibrations then cause the eardrum to move, which causes the hammer and then the anvil and finally the stirrup to move. The stirrup is attached to the oval window. Behind the oval window is the cochlea, which is filled with fluid. The mechanical energy is transferred into the fluid. As the fluid oscillates back and forth, tiny hair cells along the inner wall of the cochlea are forced to move which in turn sends electrical signals along the auditory nerve to the brain. This is where the mechanical energy is converted to electrical energy. The electrical energy travels to the brain and a 'sound' is heard.

The energy of a visible light wave determines the brightness of the light. You are able to see an object because light reflects off of the object and into your eye. The type, or color, of visible light, that you see is determined by the particular frequency of light that enters the eye. The separation of light and the formation of rainbows are due to refraction. When visible light travels through a denser medium like a prism the light slows down. As visible light slows down it bends or refracts. White light consists of a wide range of frequencies, 400-700 nm, and each wavelength of light will bend at a different angle. As a result of the different angles of refraction the colors separate into the visible spectrum commonly known as Roy G. Biv. Violet light refracts the most because it has the highest frequency and therefore the shortest wavelength. Red refracts the least because it has the lowest frequency and the longest wavelength. That is why red is always on top in a rainbow and violet is on the bottom except in a double rainbow.

Concepts such as reflection and refraction are normally presented using light as the theme. Little information is provided in the texts about the reflection or refraction of sound. The law of reflection is easy to observe using light rays, but students can hear the energy reflecting when using sound waves. Refraction, the bending of waves as they travel from one medium to another of different density, can be seen using light. However, refraction of seismic waves is how we know that the earth's structure consists of different layers. Refraction also describes long shore currents and the effects of weathering and erosion on a shoreline. Another phenomenon discussed mostly in terms of one type of wave is the Doppler effect. Most textbooks describe the Doppler effect as the apparent change in pitch of a sound due to movement of the observer or the source. It would be more accurate to describe the Doppler effect as the apparent change in frequency of waves so that it would also apply to light. The formula for wave speed is $v = \lambda f$, for all types of waves. The actual speeds vary greatly from sound to light to seismic waves but the formula and process for calculating speed remains the same.

Using sound and light as examples is the traditional way of teaching waves. Most textbooks, at this level, have a chapter on waves and sound together and then a chapter or two on light and wave interactions. Students seem to learn that sounds are waves because they are in the same chapter. Because light is discussed in separate chapters this connection is sometimes lost. In essence, the textbooks suggest to students that light is more important than sound and any other waves for that matter by simply having more pages on one topic than another. Recently, textbooks have included connections to seismic and water waves in the areas where sound and light are discussed.

Demographics

Birmingham Public Schools serve more than 7,600 students in grades K-12 from ten large residential communities with a combined population of 80,000 persons. The community is composed primarily of professional and business families. There are 13 schools: eight elementary, two middle schools, two high schools and a unique district wide school of choice with a science and technology emphasis for grades 3-8. Students from Birmingham Public Schools consistently score high on state and national standardized tests.

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Seaholm High School is one of Birmingham Public School District's two comprehensive high schools for grades 9-12. Seaholm High School is fully accredited by the North Central Association of Colleges and Secondary Schools and the University of Michigan. Each student is required to complete two credits in science and two in math with one additional credit in science or math.

The school follows a block schedule with seven 50-minute classes on Mondays and 95-100 minute block classes on Tuesdays-Friday (Appendix A-III). Classes meet three times per week: Monday, Tuesday, Thursday or Monday, Wednesday, Friday. Tuesdays and Thursdays there are late starts (Appendix A-III) so students only have three block classes, the morning is set-aside for students to come in for extra help. T-Block is 'Teacher Block' and is used for staff development time. S-Block is 'Student Block' and is designed for students to come in for extra help, use the media center, or to do make up work. Classes on Tuesdays and Thursdays are 100 minutes and Wednesday and Friday classes are 90 minutes. The reason for the difference is simply more instructional time was needed to meet the state requirements for minutes of instruction. Seaholm chose to shorten the 'T' and 'S' block times and extend the classes on Tuesdays and Thursdays to meet the required time.

Seaholm has a student population of 1,041 with an average class size of 21. Seaholm is 96% white, 3% Asian and 1% black and Hispanic combined. On average approximately 80% of Seaholm graduates go on to 4-year colleges and approximately another 10% go on to 2-year colleges.

I teach the entry-level ninth grade science course, Universal Science and Technology. Biology is an option for ninth graders who are in the honors math track. On average, 80% of all incoming ninth graders will take Universal Science. My average class size is 24 students. The students come from primarily two different middle schools. However, I do have students that are coming to public schools for the first time. The background knowledge of my students varies greatly based on which middle school they attended. I have found that in our own school system two students from the same middle school will have very different backgrounds because the depth at which the objectives were covered varied from teacher to teacher despite having a set list of objectives to teach. In addition, about 10% of my students receive modifications and or accommodations depending on their individual education plans. Another 5% of my students are repeating the course.

Pedagogical Review

According to the National Science Education Standards there are basic fundamental themes of education: science is for all students, learning is an active process, and improving science education is a part of a system of education reform (Texley, 1998). There are two ways we remember new information. The traditional classroom emphasizes one method, which is memorization of isolated facts and concepts. A second method is based on the theory that our minds organize pieces of related information into complex webs, called schemata. A thematic approach takes advantage of this process by having all the subjects revolve around a central theme, thus enabling students to develop complex webs of interconnected information (Peters, 1995).

Teachers are always looking for curricular connections to help students comprehend concepts by exposing them to multiple perspectives. The National Science Education Standards emphasizes the need to present unifying concepts and processes such as modeling throughout the curriculum (National Science Education Standards, 1996). Concepts are often introduced and taught as sequential but isolated topics: "We are done with sound so let's go on to light." Teachers seem to believe that they are making the learning manageable by breaking it down in to specific units but this can often lead to misconceptions. The most common misconception that I have encountered is that since sound and light are taught separately they must be unrelated. Some students even develop the notion that math is unrelated to science. For example, while scheduling classes for next fall a group of juniors asked the physics teacher if they were going to use math in Honors Physics.

A better approach is to teach multiple topics that may initially seem different but ultimately have a common basis (Hartley, 1999). According to Don Tapscott (Tapscott, 1998), "Give children the tools they need and they will be the single most important source of guidance on how to make the schools relevant and effective." Students need to be given not only basic information but also an avenue to apply that knowledge to elicit further learning. New information becomes meaningful when it is integrated into our existing knowledge. Therefore, developing integrated units, using the thematic approach, is good for both students and teachers (Texley, 1998).

If students can develop the skills to organize their thoughts and look for similarities between topics, then the level of learning is greatly increased. Instead of reviewing basic terminology the instructor should implement the information. One way for students to see these similarities is through laboratory exercises and other applications, such as projects and performance assessments that use and reuse the terminology. If students can learn that terms maintain their basic meaning even when applied to different topics then they can build on their previous knowledge instead of starting at ground zero. "The goal is to think and organize [similarities in acquired knowledge] in terms of systems" (Aldridge, 1996). To achieve this the teacher should thoughtfully integrate ideas to facilitate greater learning for the students and to develop skills to apply science in everyday life.

The Standards developed by the NSTA suggest that content be delivered in ways that are developmentally appropriate, interesting, and relevant to everyday life. Making science applicable is a way to capture student interest while promoting inquiry (Texley, 1998). In order to achieve this, however, students must be actively engaged in science through inquiry and other scientific investigations with various levels of hierarchy. Teachers must provide an environment that allows the students to learn because the amount of material to be covered is constantly increasing. The amount of knowledge to be learned is overwhelming for students and teachers and new knowledge is being constructed at a rate that is equally overwhelming (Hegarty-Hazel, 1990). Without a means to organize, categorize, and conceptualize the information presented the students will have difficulty in learning new information. "The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once" (Aldridge, 1996).

Another approach leaves a lasting effect on both the students and the teacher. Embedded assessment, also known as continuous or classroom-based assessment, enables the teacher to modify instruction based on the immediate feedback of the students. Teachers need to communicate with learners, to tell them what is expected, ways to improve, listen to their concerns, and assess their strengths and note their difficulties

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(Bentley, 1992). By sharing understanding and providing feedback teachers are able to make adjustments to their instruction as they try to meet the needs of the students. As teachers become more responsive to their students' understanding of the material, the students become more positive about the class. As students become more positive they become more focused and their level of understanding and achievement also increases (Gallagher, 1999).

In this unit on waves I incorporated aspects of chemistry, physics, earth science, biology, anatomy, as well as writing, reading, art, mathematics, history, music, and technology. This thematic approach is a perfect fit for my teaching style, the required curriculum, and the age of students being taught. It also is in line with the current research on learning. Coherent integration of topics not only increases the depth of understanding but the breadth of content coverage (Texley, 1998).

According to Bransford, in the book How People Learn (1999), "research on learning has uncovered important principles for structuring learning experiences that enable people to use what they have learned in new settings." In the situation reported in this paper students were introduced to wave properties while doing laboratory experiments on sound. The students then were given similar exercises involving light and the students were expected to use that knowledge they gained previously when studying sound. The goal was to teach the students how to use what they have learned to help them as they continue on as learners.

Schools have an obligation to provide students with opportunities for learning and acquiring the skills needed to be a learner. Ideally, schools should instill the desire for learning and growing that will enable students to be productive members in their cc

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communities. The best hope for educators is in new ways to teach students how to learn. "Students cannot take command of their own learning when they lack the knowledge and skills to learn meaningfully" (Hegarty-Hazel, 1990). Students do the experiments but do not see the meaning of the events. In essence we need to help them understand the nature of science itself. By teaching students how to learn the schools are providing them with the skills they will need outside the high school doors.

> "The goal of education is better conceived as helping students develop the intellectual tools and learning strategies needed to acquire the knowledge that allows people to think productively and contributes to the individuals' understanding of learning that can assist them in becoming self-sustaining, lifelong learners" (Bransford, 1999)

As teachers we need to teach the students the content of the course and how to learn so that they can grasp major ideas and apply that knowledge across the curriculum and outside the classroom. The more often the material, content, is introduced in different contexts the more likely the information will be learned. It is our duty as teachers to provide an experience for students that help them to facilitate the greatest possible learning (Hegarty-Hazel, 1990).

By using a thematic approach to teaching real world applications, a little of the constructivist approach, and embedded assessment I have developed a unit with very tangible objectives for students of various learning abilities and styles. This unit was designed to engage the students in an engaging and worthwhile experience. The reason we can appreciate the world is that it has structure that is interesting, sensible, and related to our very selves (Rosen, 1998). Science can be fun.

IMPLEMENTATION OF UNIT

Introduction

This unit on waves was developed at Michigan State University during the summer of 2000 by significantly revising the original units on waves. Originally, sound, light, and earthquake waves were taught as separate mini units with a brief comparison between types of waves at the end. This new unit was designed to fully integrate the phenomena of sound, light, and earthquakes using the basic properties of waves as the focus. The different types of waves were used to emphasize various properties of waves. For example, when discussing speed of waves in relationship to distance and time it is more tangible to the students to study sound waves, which travel at a speed that is comprehensible to them. When analyzing the behavior of waves when they encounter a barrier it is easier to use light as the focus so the students can actually see what happens. Earthquake, or seismic, waves are a natural way to show the impact of waves on society and the advancements and limitations of technology in our world today.

The main difference between the new and the old units is the integration of the three units on waves. Instead of studying earthquakes for three weeks, sound for two weeks, and light for three weeks, students engaged in an eight-week unit on waves. Laboratory exercises were modified to include pre-lab questions. Mini/pocket labs also were also developed and others adapted to introduce topics, which were then explored in greater depth in other experiments. Long-range projects and performance assessments embedded into the unit were added to the unit in order to assess and measure in-depth thinking skills (Brookhart, 1999). Each lab was designed to lead into the next activity.

This year for the first time I used a textbook (Dobson, 2001), which has served as a great resource for some of the slower students and also as an avenue to challenge some of the more advanced students.

The unit began with simple lab experiments and students focusing on writing hypotheses and answering questions in complete sentences. Each lab write up then included one more component until the students were writing full laboratory reports. The students began laboratory report writing by focusing on their hypothesis, forming an educated guess before they begin the exercise. The focus then was directed towards the recording observations and answering of questions component. The students practiced designing tables to place measurable data. Eventually each portion, component, of a full laboratory report was implemented. Integrated in between the lab experiments were other writing activities and projects to assess their knowledge and provide ownership and control by the student (Brookhart, 1999).

This new unit was implemented the first week of school (Appendix A-IV). In the past I started out by slowly reviewing topics from middle school, going over measurement and the scientific method. This time, the first activity was a laboratory exercise. The students jumped head first into science and the mood was set for the semester. The unit was planned for seven weeks, allowing two weeks for adjustments, since this would be the first time the unit included so many new activities and laboratory exercises.

The unit began with frequency versus wavelength and properties of waves, which led into calculating speed. Discussion followed, illustrating the differences and similarities of various waves. Also, instead of teaching measurement as a separate activity it was integrated into the appropriate laboratory exercises. Writing, music, and art activities were also incorporated to appeal to those students who have a more creative side.

Since this is a semester course the unit on waves was implemented again in January with a new set of students. Therefore data in the fall will be referred to as 'Semester 1'. This data was analyzed and the material reevaluated if needed for a second implementation in January, which will be referred to as 'Semester 2'.

One factor of concern was the time of day the classes met. The unit was implemented into all five of the Universal Science and Technology courses that I taught, 112 students for first semester and 116 students for second semester. It has been my experience that the ninth graders in the afternoon block tend to have a lower class average than the other classes. There are a couple of factors contributing to this: 1) tracking in math. The lower level math classes were offered in the morning, leaving the lower tracked students to take science in the afternoon and 2) students have four block classes on Wednesdays and Fridays and by the end of the day they are too mentally tired to focus on the fourth 95-minute class. As a result of fewer academic offerings in the afternoon the afternoon classes tend to be larger and that may have had some effect since I didn't have the opportunity for as much individualized attention as in the morning classes. It has been suggested that the reliability of the posttest scores is likely to represent consistent, typical performance for the students if performance does not depend on time of day or other external factors (Brookhart, 1999).

All students were given the consent form and only 153 students, 67%, returned it (Appendix B-I). Of the 153 students who returned the form, 152 agreed to me using their data. The

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data. The primary data came from pre- and post surveys and pre- and posttests (Appendix B-II, B-III, B-IV). Evaluation of the unit was made by comparing the results of the students' pre- and post surveys and in their responses to certain questions on the pre- and posttests. The survey data provided a rough idea about how much the students believed they learned as a result of the unit. The comparison of responses on their pre- and posttests allowed me to see what the students actually learned from the unit.

As I describe the effectiveness of the unit I will be using mostly group data results from the surveys and pre- and posttests. Logistically, it was too difficult to monitor 152 individual students performance on individual activities and assignments. However, the specific responses on the pre- and posttest from six students will be discussed. Two above average students, two average students, and two below average students were chosen. One student from these three levels of performance, in my opinion, was selected from each Semester group. The choices were made after their grades were turned in. The students will be referred to as Students A, B, C, D, E, and F in this thesis (Table 1).

Table 1: Description of Students Chosen for Qualitative Evaluation

STUDENT	PERFORMANCE LEVEL	SEMESTER
A	Above average	1
B	Average	1
C	Below average	1
D	Above average	2
E	Average	2
F	Below average	2

Students' grades on the posttest and final quarter grades were used to compare student achievement in relation to the time of day as a qualitative analysis and not as an evaluation of the unit. Scores were also compared between the Semester 1 group and the

Semester 2 group. This comparison between first and second semester was done to see if the students would do better after having the first semester of a block schedule to get acclimated and after having a semester more of math and science. The students' quarter grades were based on homework and laboratory reports. Analysis of the responses to the students' pre- and post survey and pre- and posttests will be used to evaluate the overall effectiveness of the unit. It is unrealistic to evaluate each response on every homework assignment and laboratory report. However, since the posttest was designed to evaluate the material covered in the homework and laboratory activities it is a fair determination of the success of unit and its design.

The *Wave Album* project (Appendix C-I) was designed as a performance assessment. The students were to collect pictures of waves and classify the pictures as examples of longitudinal or transverse waves and as electromagnetic or mechanical waves. Unfortunately, the project was implemented differently for the two test groups so data were not collected for evaluation of the unit for this thesis. However, the feedback from the first semester group did affect the change in the due date for the second semester group based on class evaluations. The students' opinions stated that they thought it would have helped them learn the terminology better and their understanding of the uses of waves.

Summary of Activities

Numerous activities were included in this unit ranging from long-range projects, and laboratory exercises to class activities and homework assignments. Table 2 shows the order of presentation of each activity along with a brief description of each activity.

Table 2: Summary of Activities

Name of Activity	Description	Appendix
Wave album*	Performance assessment	C-I
Rulers are Noise Makers Too*	To determine the relationship between wavelength and frequency	D-I
A slinky, a slinky…	To observe transverse and longitudinal waves	D-II
Drawing waves*	To illustrate properties of waves	E-I
Amplifying Sound Using Resonance*	To use resonance to amplify sound	D-III
Mach-1*	To determine the speed of sound	D-IV
What's your mach? *	To determine the ratio of a person's speed to the speed of sound	D-V
V = d/t	To calculate speed…	E-II
Doppler Effect	To describe how a sound changes due to movement	D-VI
Instrument Building*	Performance assessment	C-II
Paths of Light and Lines of Sight	To determine the relationship between real distance and depth distance	D-VII
What's your angle?	To measure angles	E-III
Reflection Challenge	To determine the relationship between the angle and number of images	D-VIII
So you say light bends?	To observe refraction	E-IV
Penny in a cup	To observe how light bends	D-IX
Glass vial lab*	To compare observations of a glass vial to a convex lens	D-X
Microscope lab*	To apply rules of optics to a microscope	D-XI

*Denotes a new activity.

Wave Properties Using Sound

The students were introduced to the properties of sound by using various demonstrations. First I did a couple of demonstrations that produced sound. Next I asked for a few volunteers to make sound with various instruments that I gave them: a tuning fork, a whirl tube, and a singing rod. The class was asked to write down how the student volunteers were able to produce sound. Then I asked the volunteers to change the amplitude of the sound that they were producing, which led to further class discussion. I then asked the volunteers: How could they change the frequency of the sound? The volunteers could ask for assistance from the class if they didn't know the answer. By doing this activity I was able to make a brief evaluation of how much the class as a whole knew about the basic properties of sound.

Many students had misconceptions about volume and frequency of sound. They thought that as the frequency increased the volume did also. I had anticipated the confusion, which is why the first laboratory activity dealt with the relationship between the length of a vibrating object and the frequency of sound titled *Rulers are Noise Makers Too!* (Appendix D-I). Before the exercise the students were given prepared notes on frequency, wavelength, and amplitude of waves (Appendix F-I). From this activity the students could see the relationship between the length of one oscillation, the wavelength, and the frequency of many kinds of waves.

The second activity involved making waves with slinkys; *A slinky, a slinky, a wonderful, observational, demonstrational toy* (Appendix D-II). Before the lab I explained the difference between a longitudinal and a transverse wave and demonstrated how to model each with the slinky (Appendix F-II). The students were reminded that the waves they were seeing were mechanical waves because the slinky consists of matter. Therefore the transverse wave they saw was a good representation of a secondary seismic wave but only a model of a transverse light wave. The properties of mechanical and electromagnetic wave were also introduced before the activity began. To make sure the students knew what their "waves" should look like we practiced drawing waves, both transverse and longitudinal, with increasing and decreasing frequency and increasing and decreasing amplitude, using individual dry erase boards.

The ideas that the students should have grasped were that the amplitude of a wave can change without changing the frequency or the wavelength and that the speed of a wave is dependent on the medium in which the wave is traveling (Appendix F-III). The students easily grasped the second idea but struggled with the first. Based on this, I developed an activity based on drawing waves (Appendix E-I). Using a record player, we practiced drawing waves by altering the amplitude without changing the frequency. To evaluate the students' level of understanding, they were given an open notes pop quiz in which they were to match various pictures of sound waves with descriptions of specific volumes and pitches.

Since many of the students started to ask questions about how and why they hear we took a day to discuss the ear and hearing. First we discussed the range of human hearing and the range of frequencies for infra- and ultrasound (Appendix F-IV). This comparison provided a wonderful opportunity to compare terms used to describe sound with terms used to describe light. When students see that prefixes added to different words still maintain the same basic meaning, they see the subject as interesting and they learn (Rosen, 1998). It was explained that electromagnetic waves we can see are called visible or white light. Most students were familiar with Roy G. Biv, but were unaware that each color is a particular frequency (Appendix F-V). Roy G. Biv is a pneumonic device for the visible light spectrum with each letter representing a different color in order from lowest to highest frequency: red, orange, yellow, green, blue, indigo, blue, and violet. The students then realized that infrared was light with a frequency lower than red and ultraviolet is light with a frequency higher than violet (Appendix F-VI). Discussing hearing also provided an excellent opportunity to explain the transformation from mechanical to electrical energy.

Amplifying Sound using Resonance was the next lab, focusing on the concept of resonance (Appendix D-III). The students already knew that amplitude refers to the energy and, in the case of a sound wave, the volume, but the term resonance hadn't yet been introduced. Some students were becoming quite engaged as evidenced by their questions: "Is that why a guitar is hollow?" or "Is that why pianos are made out of wood?"

Calculations Involving Waves

Mach 1 (Appendix D-IV) and *What's your Mach?* (Appendix D-V) introduced mathematics into this unit. Instead of being given the formula to calculate speed, the students determined the speed of sound and then a person's running speed. The majority of the students knew that speed is equal to distance divided by time but did not know how to use the proper units (Appendix E-II). I coordinated the methods that the math department uses in Algebra I and Pre-algebra in teaching velocity.

Next, the students calculated the speed of sound in air by resonating a column of air at a known frequency. I made 'graduated cylinders' and 'hollow tubes' out of PVC pipe instead of glass, which were cheap and unbreakable. This activity reinforced one of the outcomes from the *Amplifying Sound using Resonance* lab.

Doppler Effect

Sound was used to introduce the Doppler effect since students can hear the change in the pitch of a sound when the source of the sound is moving (Appendix F-VII). The Doppler effect was connected to the 'red shift' and to Doppler radar. A wonderful demo of the Doppler effect is to strike a tuning fork and then swing it around or to simply toss around the room a buzzer or other device that emits a constant sound (Appendix D-VI).

Instrument Building (Appendix C-II)

One week of class was used for the students to build musical instruments working in groups of four. This project was designed as a performance activity and covered many of the Michigan Essential Goals and Objectives for Science Education, MEGOSE (Appendix A-II). Students also explained how a sound recording or reproducing device works, which is MEGOSE objective PMV13. This activity provided the opportunity for the students to design, build, and demonstrate their knowledge on how musical instruments produce sound and how the frequency and volume of the sound of an instrument can be varied.

Wave Interactions Using Light

Light was used to study the interactions of waves: reflection, refraction, interference, and diffraction. The first lab on wave interactions was on reflection (Appendix D-VII). The students placed an object at a specified distance in front of a plane mirror and then marked where they perceived the image of the object to be located.

The students then repeated the lab with a 'reflect a view'. The students graphed the real distance versus the depth distance to determine the relationship between the two variables (Appendix F-VIII). The techniques for graphing were introduced to many and reinforced for some during this exercise. Students were to evaluate their data and draw a line of best fit while also contemplating whether or not their line should go through the origin.

The Law of Reflection was introduced through a lab using plane mirrors and a single beam of light that was reflected from the plane mirror at various angles. *What's your angle?* (Appendix E-III) was used to review the skill of measuring angles and reading protractors. The students analyzed their data by marking the normal and measuring the angles of incidence and angles of reflection (Appendix F-IX). As a challenge, the students they were asked to determine the relationship between the numbers of images seen versus the angle between two plane mirrors (Appendix D-VIII).

Using the Light Boxes sold by Arbor Scientific, the students' explored reflection by placing curved mirrors in the path of three parallel beams of light. These light boxes are able to emit a single beam of light or multiple parallel beams of light. Each Light Box kit also contains plane and curved mirrors, an assortment of lenses, and colored slides that provides the opportunity for the students to experiment with light on their own. The students were able to see that concave mirrors do indeed converge light rays and cause them to cross at the focal point and the convex mirrors diverge light rays (Appendix F-X). To reinforce the notion that each point on the curved mirror obeys the law of reflection, the students set up a series of flat mirrors in a curved path much like a concave mirror. They traced the path of parallel beams of light hitting the pattern of mirrors and then noticed that the light rays also converged as with the concave mirror.

I soon noticed that the students were designing their own experiments to see what happened when they sent light rays through the various lenses in the light box kits. The students discovered refraction on their own, requiring only the name to attach to the phenomenon that they observed (Appendix F-XI). The students were given a mini activity on refraction (Appendix E-IV).

Penny in a cup (Appendix D-IX), rather than being an introduction to refraction served as an application of what the students saw using the light box and lenses. The students observed refraction through plane lenses and curved lenses (Appendix F-XII). The concepts of converging and diverging paths of light were applied to lenses and the similarities and differences between curved mirrors and lenses were discussed. As a challenge the students were given a glass vial filled with water and an index card with the words CARBON (in red) and DIOXIDE (in blue) written on it. The students were asked to view the words through the vial according to the directions found in the lab (Appendix D-X). After discussing their findings the students could see the similarities between the water filled glass vial and convex lenses. Some students also noticed that air bubbles in the vials behaved like concave lenses, a wonderful surprise. The students were applying concepts to observations.

One day was taken to regroup and go over vocabulary that the students had encountered during their laboratory experiences to make sure that they were keeping the concepts of reflection and refraction separate in their minds. As an introductory activity the students took notes on the definitions of reflection, refraction, diffraction, and interference. The discussion also reviewed characteristics of waves and the differences and similarities that they have seen so far between sound and light waves. The Venn diagram (Figure 1) was generated as a class during each semester of the unit.

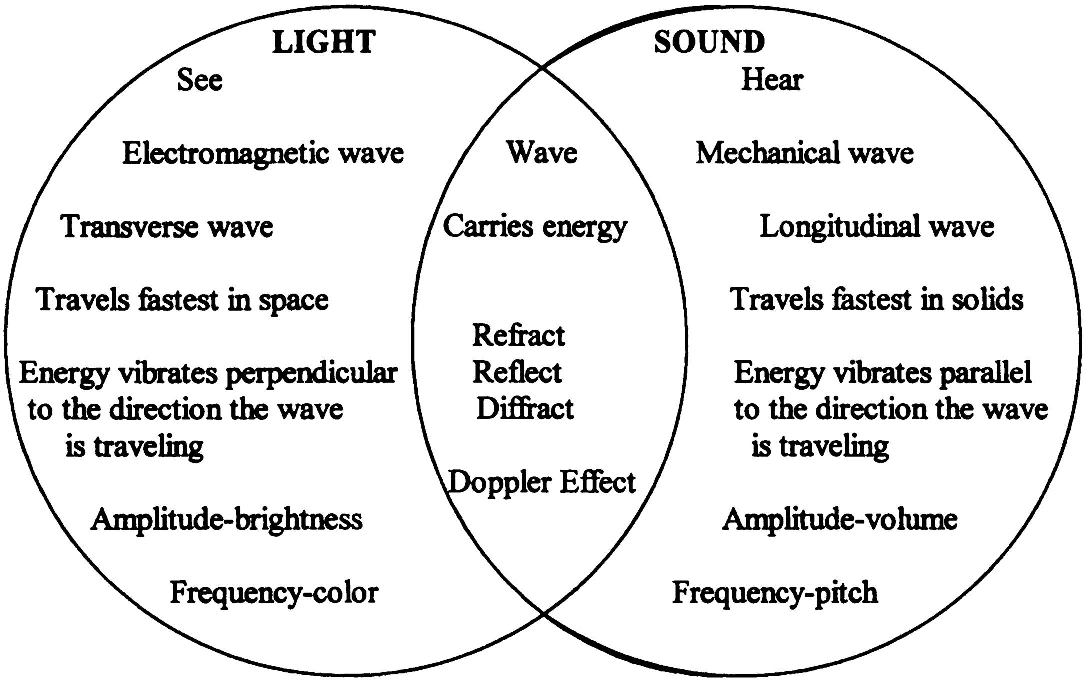


Figure 1: Venn Diagram- Light and Sound

The slinky was used once again to show the students reflection of a wave. The students watched the wave pulse travel down the slinky and travel back but on the opposite side. Newton's Third Law of Motion was discussed as an explanation to the phenomena of the pulse bouncing back. The pulse bounces back on the opposite side in which it originated. Newton's Third Law: For every action there is an equal an opposite reaction. The class asked questions about SONAR and ultrasounds. It seemed that the students were able to comprehend sound bouncing, reflecting, off a wall.

Refraction was then demonstrated using a long spring attached to one end of the slinky. As wave pulses were sent down the slinky the students could see that some energy did travel into the spring and also energy reflected back down the slinky. The students asked if that was why there was also a reflection when they shone their light beams into the various lenses. They also wanted to know if that was why they saw rainbows coming out of the triangular prisms. Before going on to color of light the students were asked to identify the parts of various drawings on the board: angles of incidence, angles of reflection, angles of refraction, normal, incident ray, reflected ray, and refracted rays. Once this was done there was a quick review of how to recognize if something was a mirror or a lens based on the light rays drawn.

The idea was to implement the microscope lab (Appendix D-XI) at this point. Due to time constraints this laboratory exercise was done as an extension after completion of the unit. The decision was made to leave this activity for the last week of the quarter when the students would be preparing for midterms in their other classes. By placing this exercise later in the unit, I was able to administer their unit test (posttest) at a time that seemed less demanding from their other classes. The belief, on my part, was that the students might perform better when they weren't busy studying for midterms in all of their other classes.

Color

The separation of white light into its component colors was demonstrated to the class by placing a folder over the screen of the overhead with just a small slit cut in it so only a small beam of light is projected onto the wall. Next a card with a piece of diffraction grating in the center was placed in front of the projecting lens and the color spectrum shown on the wall with violet closest to the center white beam and red furthest out (Appendix F-V). The students were given a spectroscope to observe the spectrum of the classroom fluorescent lights and the spectrum from the natural light coming through the windows. If white light can be separated into all the colors, what happens if the colors are put back together? The students were quick to say black, thinking of pigment and not light. Once again using the light boxes the students experimented mixing light of different colors. They were given some specific combinations to try: red and blue, blue and green, red and green… and then they could design their own experiments.

The final activity was blowing bubbles to show constructive and destructive interference. The concepts of superposition were illustrated for the students using the slinky before getting the bubbles out.

Posttest

The final day of the unit was spent completing the post survey (Appendix B-II) and the posttest (Appendix B-IV), which was modeled after the pretest. The posttest consisted of a series of multiple-choice questions followed by fill in the blank, true/false (where the false needed to be corrected to make them true) and some performance objectives. The remainder of the posttest included the short response questions from the pretest, a wave diagram in which the students were to label the parts of a wave, and a Venn diagram, which the students were to generate on their own on light and sound. The data analysis was based on five specific questions: three short response and two diagrams (Table 3).

Table 3: Questions Used in Analysis of Pre- and Posttests

Pre-	Post-	Test Question
#3	#34	Identify the parts of a wave.
#1	#35	What is a wave? (What determines how and where it can travel.)
#4	#36	What affects the speed of a wave?
#5	#37	How do waves apply to life? (What are some applications of waves in every day life? —Be specific and explain)
#9	#38	Complete a VENN Diagram on sound and light.

Due to the calendar of events at school, topics such as vision, how microscopes work (Appendix D-XI), and using seismic waves to determine information about earthquakes were done after the posttest but were still part of the same marking period along with the rest of the waves topics (Appendix A-IV).

EVALUATION

Evaluation of this unit required consideration of several factors. Most importantly, were the students able to successfully comprehend the material as a result of this new unit? Quantitative data from surveys and pre- and posttests were evaluated. Specific responses from six students were compared along with random samples taken from laboratory reports, homework assignments, and pre- and post lab discussions for a more qualitative look at the data. Other factors considered included: the different time of day that the class was offered, the difference between semesters with the Semester 2 group already having completed a semester of science and math before being introduced to the unit, and the effect of a block schedule (Appendix A-III).

Quantitative Analysis from Student Surveys

The student survey responses indicate that the students believe that they learned something. The students' responses on the pre survey for Semester 1 (Appendix G-I) and the Semester 2 (Appendix G-II) ranged from 0 to 4, with the most common response varying from question to question. The survey, its questions and scale, can be found in Appendix A-II. The average response, for each question on the pre survey, (Appendix G-III) illustrated that as a class the students probably had heard the terms but really weren't sure what they meant. The average response on the pre survey ranged from 0 to 2. On the post survey the students' responses for Semester 1 (Appendix G-IV) and Semester 2 (Appendix G-V) once again ranged from 0 to 4, but this time the most common response was 3 (Appendix G-VI). The students believed that they had a good solid understanding of the objectives on the survey as seen in their responses. It is evident that the students believed that they knew more information at the conclusion of the unit each semester. This evidence is seen in the comparison of the average pre- and post survey responses for Semester 1 (Figure 2) and for Semester 2 (Figure 3).

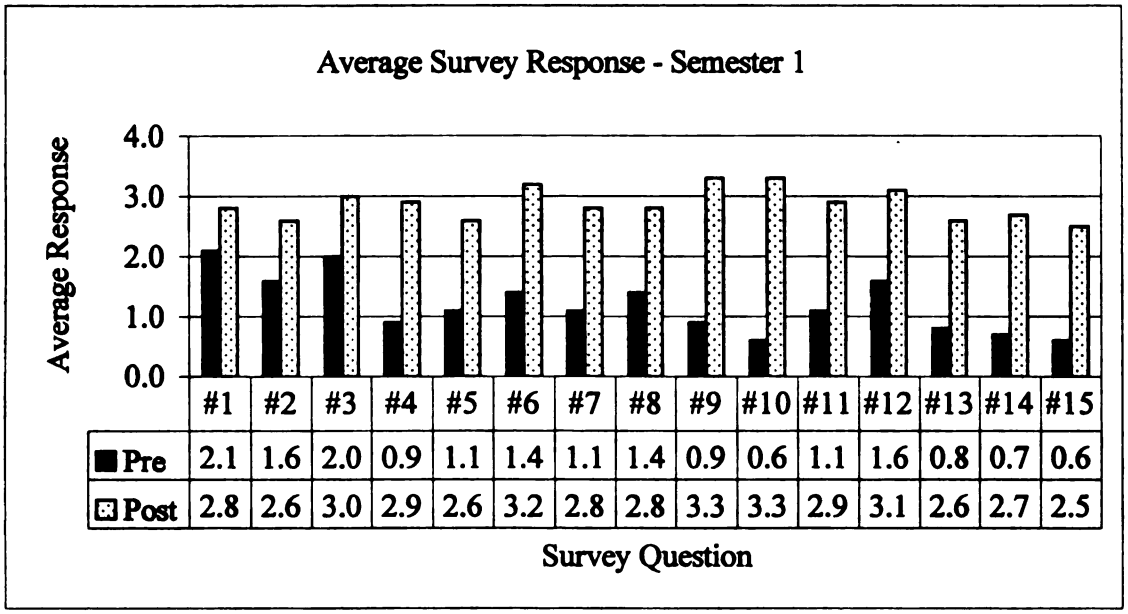


Figure 2: Average Survey Response – Semester 1

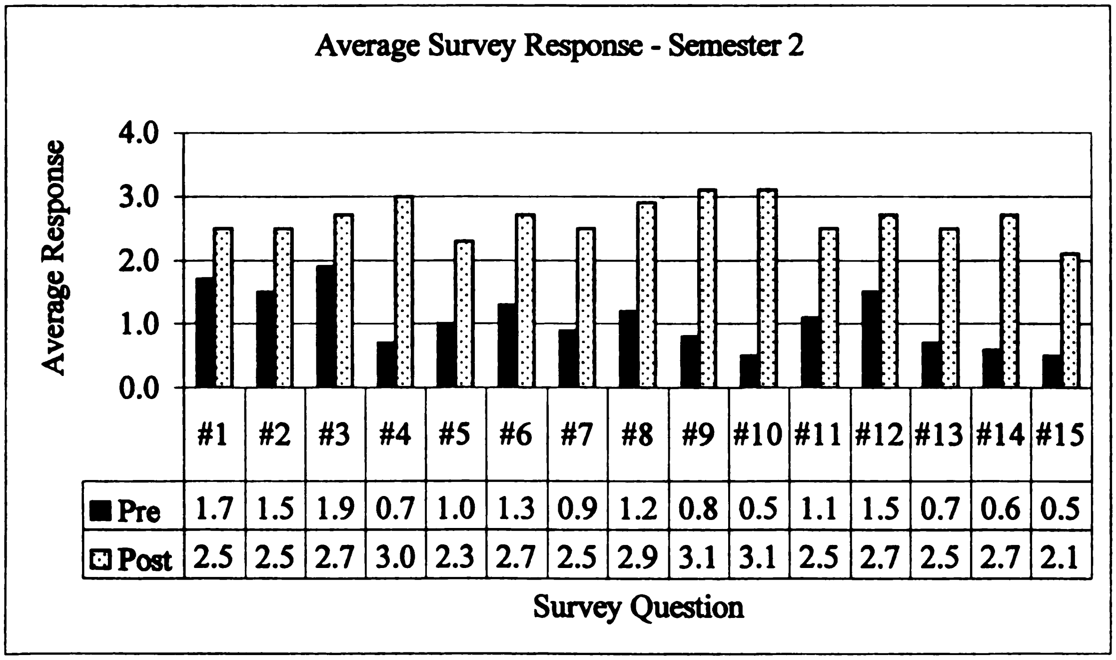


Figure 3: Average Survey Response – Semester 2

There doesn't appear to be any real difference between Semester 1 as compared to Semester 2 from the students' point of view in the post survey averages. The students all believe that they knew more science at the conclusion of the unit. Their average response on the post survey for every objective for Semester 1 and for all but two objectives for Semester 2 was that they had a good, solid understanding of the objective. This data seems to support the idea that Semester 2, having already completed one semester of science and math, didn't have an advantage over Semester 1, as I would have thought.

Quantitative Data Analysis from Pre- and Posttests

The pre- and posttests were different. The pretest (Appendix B-III) consisted of free response type questions only, whereas the posttest (Appendix B-IV) was a combination of multiple-choice, fill in the blank, true and false (correcting the false), and free response. Only the free response questions from the pre- and posttest were compared, specifically five questions (Table 3).

Table 3: Questions Used in Analysis of Pre- and Posttests

Pre	Post	Question
#3	#34	Identify the parts of a wave.
#1	#35	What is a wave? (Describe how and where it can travel.)
#4	#36	What affects the speed of a wave?
#5	#37	How do waves apply to life? (What are some applications of waves in everyday life? – Be specific and explain.)
#9	#38	Complete a VENN Diagram on sound and light.

Specific responses for these selected questions were tallied for Semester 1 (Appendix G-VII) and for Semester 2 (Appendix G-VIII). The data shows the number of students who included the listed response in their answer to the question on the pre- and posttest. The percent column shows the percentage of students from the test group that gave each response. There were seventy-six students in both Semester 1 and Semester 2. A student could have had multiple responses for each question. However, the highest possible number recorded for each specific response was 76 per semester.

The students were asked on the pretest, "What are the parts of a wave?" and on the posttest they were given a diagram and asked to identify the parts of a transverse wave. The data (Appendix G-VII, G-VIII) shows that only one student new all the parts of a wave on the pretest, however about two-thirds of the students could identify all the parts of a wave on the posttest. This posttest comparison between semesters can be seen in Appendix G-IX. Another 28% could properly identify the crest and trough on a transverse wave. The results of this question were also compared between semesters (Figure 4).

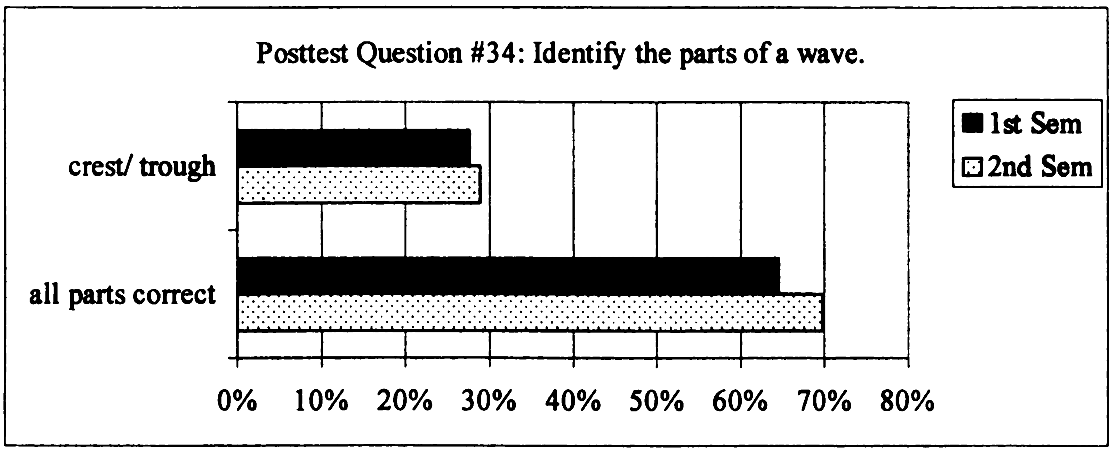


Figure 4: Posttest Question #34: Identify the parts of a wave.

The question "What is a wave?" received multiple responses. After seeing that on the pretest most students, if they put anything, wrote about movement or energy. In order to direct the students to more than a definition of a wave, discussions in class dealt with not just moving energy but how did that energy move and where. Therefore, on the posttest the question was modified to elicit more in depth responses. On the posttest the question included how and where waves travel. From the data, 86.8% of the students in Semester 2 mentioned that a wave is a disturbance, a vibration, or simply energy on the posttest a huge jump from 7.9% on the pretest. More importantly is the significant improvement in the other responses. There was also an improvement in the quality of responses in Semester 2 as compared to Semester 1 (Figure 5).

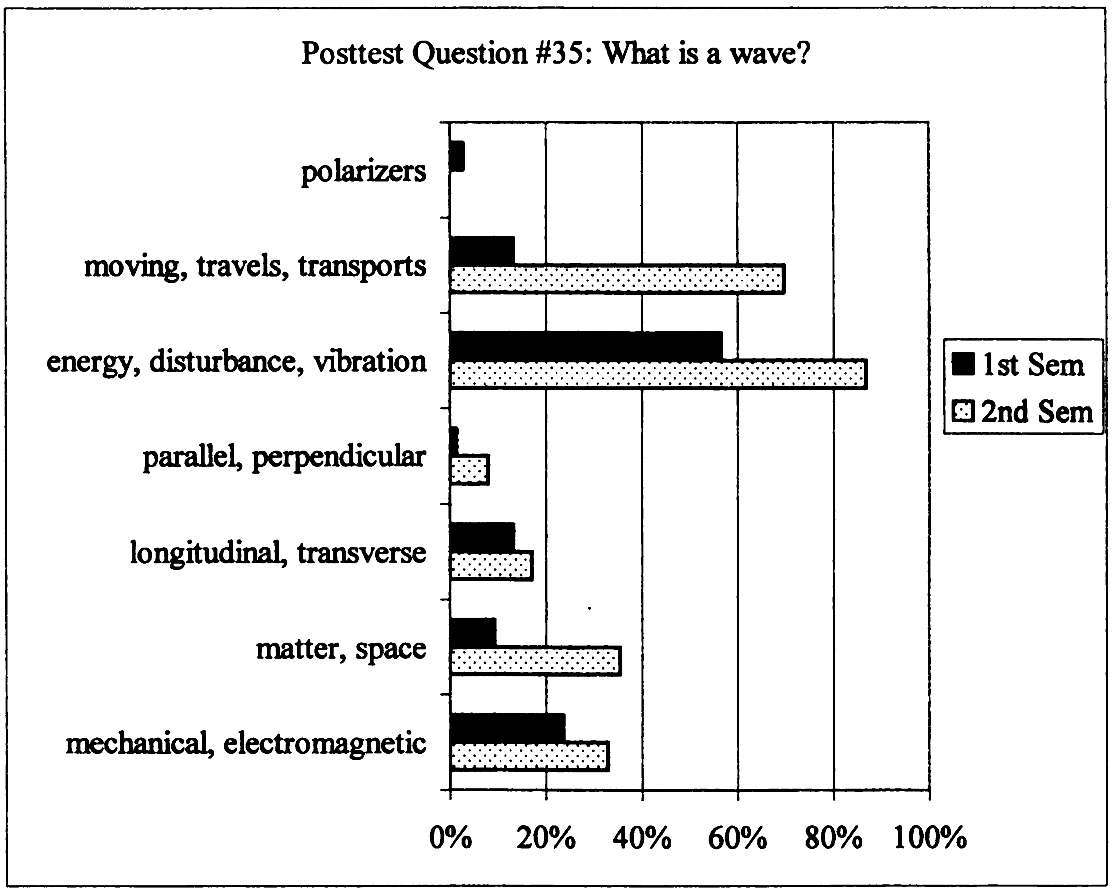


Figure 5: Posttest Question #35: What is a wave?

Since I was able to implement this unit twice I had the opportunity to make changes before it was implemented again. The only changes made were to leave more time for post lab discussions and to leave notes on the board longer. By leaving the notes from the previous day on the board until I needed to use the board again. For whatever reason, there was a sizeable difference in the number of responses that met the objectives of the question in Semester 2 as compared to Semester 1.

Both groups were aware that the density of the medium or the matter that the wave was traveling in had an effect on the waves speed, question #36 on the posttest (Figure 6).

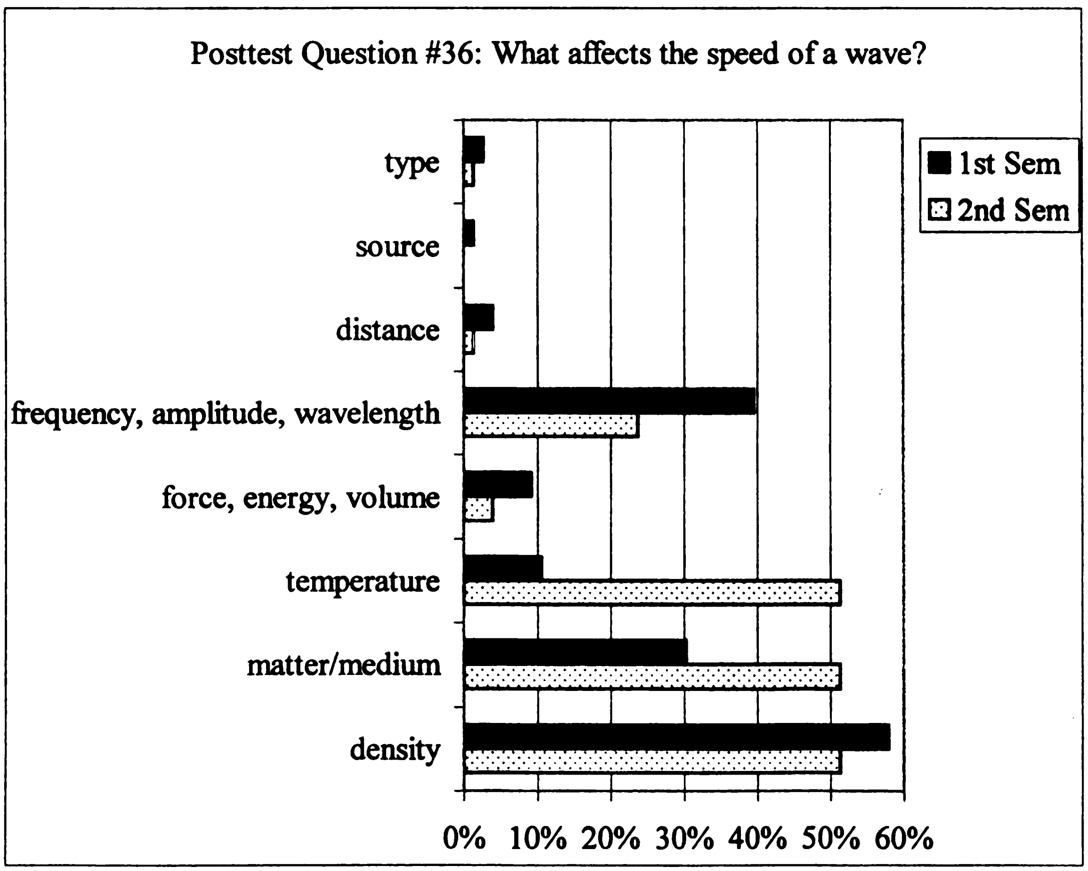


Figure 6: Posttest Question #36: What affects the speed of a wave?

However, the Semester 2 group seemed to have a greater comprehension of the impact on temperature on the speed of a wave. There were also a number of students that believed that frequency, wavelength, and/or amplitude affected the wave's speed. Class discussions specifically addressed the fact that speed is not frequency and frequency is not speed. The confusion may be attributed to the students' understanding of the word 'affects'. Some of the students, when asked, thought that the question meant how do you calculate the speed of a wave. Time was spent in class discussing and calculating the speed of a wave using $v = d/t$ and $v = \lambda f$ (Appendix D-IV, D-V, E-II, F-I, F-III). The data suggests that there was less confusion about what the question was asking since Semester 2 had fewer students report that frequency, wavelength, and/or amplitude affected the speed of a wave. There were also a small number of students in each semester that reported the force, energy, or volume of the wave affected the speed. These factors show that there needs to be a greater clarification in the wording of the question but possibly also in how the information is presented and utilized during the unit.

The idea of making the science applicable to life, the 'authentic' assessment approach, was a driving force behind changing this unit from the way it had been taught in the past. Students need to realize the impact of what they learn and how it can affect them. This thought was the reason behind posttest question #37: How do waves apply to life? The purpose was to elicit responses beyond that we need light to see and sound to hear. Unfortunately, the students' responses overall did not demonstrate a thorough understanding of the objective. Considering that there were no activities to develop this objective beyond the sound recording or reproducing portion of the musical instrument project and some brief class discussions the results are not too surprising (Figure 7). If more time had been spent dealing with actual applications of waves as a separate activity more students may have been able to give more in depth responses.

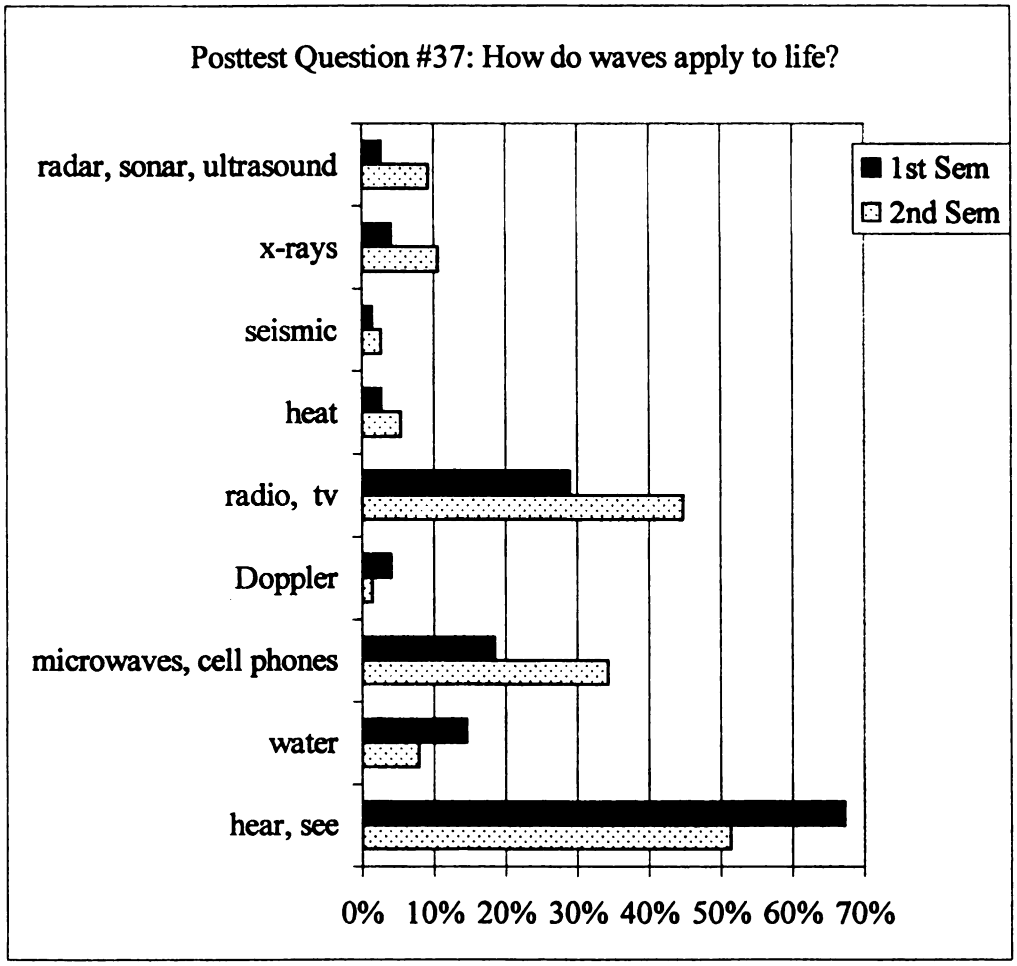


Figure 7: Posttest Question #37: How do waves apply to life?

More time will be put into developing activities to meet this objective in the future. The majority of the students still stated the use of light and sound to see and hear but they were also aware of various other uses of waves. Students could state that microwaves were used not only for microwave ovens but also for cellular phones.

The final question that was analyzed for evaluation of the unit was the Venn diagram constructed on light and sound (Figure 8).

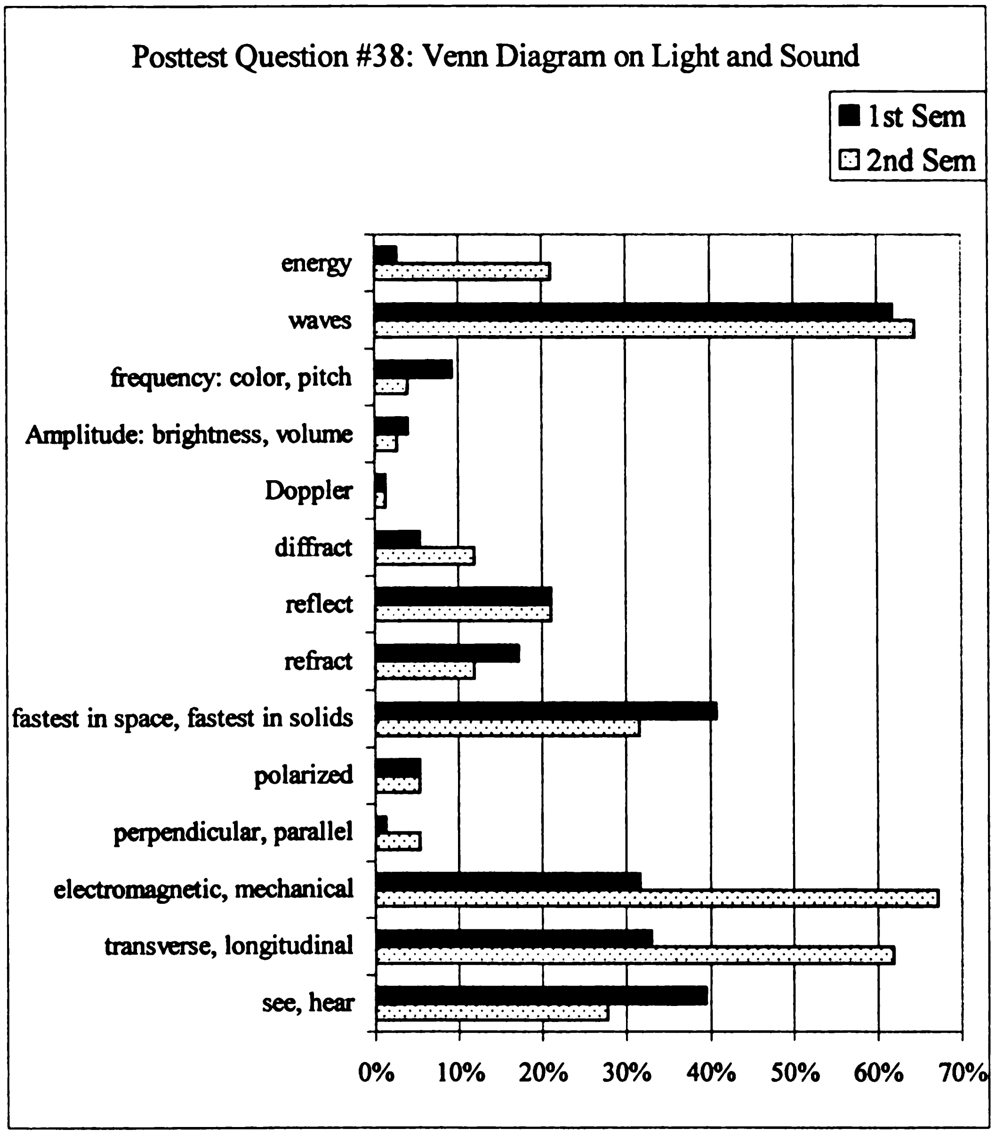


Figure 8: Posttest Question #38: Venn Diagram on Light and Sound

The data show that the majority of the students in Semester 2 knew three things: sound and light are both waves, light is electromagnetic while sound is mechanical, and light is transverse while sound is longitudinal. The majority of the students in Semester 1 could only state that light and sound are both waves. The placement of the due date for the wave album may have been a factor here. The students from Semester 1 stated, on their class evaluation forms at the end of the unit, that they had wished the wave album had been due before the unit test (posttest). They wrote, "I would have been forced to learn what electromagnetic, mechanical, longitudinal, and transverse meant before taking the test". This comment, which was found on several evaluation forms led to the change in the due date for the wave album for Semester 2. Changing the due date of the project to before the test could be responsible for more students including the terms mechanical, electromagnetic, longitudinal, and transverse in their Venn Diagrams on the posttest.

Venn diagrams can be very useful in helping students categorize ideas and to look for patterns to help them study and comprehend the vast amount of material presented to them. Possibly utilizing this diagramming style more often in the future would assist the students in being able to generate them on their own in testing situations. The diagrams were used more often in Semester 2 than Semester 1, which could also explain the differences seen in the number of responses for each characteristic between the two semesters.

Qualitative Data Analysis from Pre- and Posttests

Exact responses from six students were used to qualitatively evaluate the unit. The responses used are from five specific questions (Table 3) on the pre- and posttest. On the pretest only student A knew any parts of a wave, mentioning just crest and trough.

In regards to identifying the parts of a wave, students A and D could identify all the parts of a wave correctly on the posttest (Appendix H-I). Students B and E could label three parts correctly and students C and F could only identify two wave parts correctly on the posttest. This correlates to the students overall performance in the class. The two above average students could identify all the parts, the average students could label more than half the parts correctly and the below average students could only identify two out of the five wave parts.

For the question 'What is a wave?' it is evident that only student D had a correct and thorough response (Appendix H-II). All six students' responses were more in depth on the posttest as compared to the pretest however, students A, B, C, E, and F's responses were incomplete or contained incorrect information. This test group of six students mirrors the overall class data (Figure 5).

In the case of question #36 two students stated that frequency affects the speed of a wave (Appendix H-III). One of these two, student A, was an above average student and the other, student F, was a below average student. Part of the confusion may be since $v = \lambda f$, it appears that 'v' depends on 'λ' and 'f'; therefore 'f' affects 'v'. These responses along with the class data for question #36 (Figure 6) support that the teaching of this concept requires reevaluation.

"Light is needed to see and sound is needed to hear and radios are for listening to" were common responses from the class and the six selected students. One student, Student D, discussed applications of waves, even uses of sound waves such as SONAR, ultrasounds as in the process of lithostripsy, even though the term 'lithostripsy' wasn't used (Appendix H-IV). Once again, the six students show a true representation of both

Semester 1 and Semester 2 in the quality of their responses. On a positive note, the responses on the posttest were all correct and showed that the students did learn something about the applications of waves since the pretest. Student D, who did have a well thought out response on the pretest also showed great improvement on the posttest.

The Venn diagram on light and sound continued to support student D being categorized as above average with 10 of the counted responses in their answer (Appendix H-V). Student B, an average student, didn't have any of the responses listed in their answer to question #38. The question was worth four points, which means that they were expected to list at least four things. Being able to see and hear is counted as one characteristic. Unfortunately, the students tend to do less and hope for more.

Qualitative Data from Student Work

The first three activities were the most difficult in terms of student comprehension. The concepts of frequency and speed have been shown in the data to be an area of confusion and misconception by the students. The laboratory reports from these activities contained many incorrect responses, which appear to be caused by a misunderstanding, miscomprehension, or possibly just carelessness on the part of the students (Table 4).

Table 4: Misconceptions from Initial Laboratory Activities

Activity	Misconception
Rulers are Noise Makers Too!	When the sound is shortened it gets higher
Rulers are Noise Makers Too!	As the ruler shortens the vibrations become louder
Rulers are Noise Makers Too!	The shorter the ruler the lower the pitch
Rulers are Noise Makers Too!	When wavelength becomes shorter the frequency is faster
Rulers are Noise Makers Too!	The longer the section of ruler vibrating the louder it is
A slinky, a slinky...	Changing the amplitude made the wave go slower
A slinky, a slinky...	Increasing the amplitude makes longer wavelengths
A slinky, a slinky...	Decreasing the frequency slows down the wave
A slinky, a slinky....	Increasing the amplitude made the wave go faster
A slinky, a slinky....	Changing amplitude will change the wavelength
Amplifying Sound using Resonance	Amplitude determines frequency
Amplifying Sound using Resonance	Wavelength determines amplitude
Amplifying Sound using Resonance	Frequency is determined by how fast or slow the wave is
Amplifying Sound using Resonance	How loud or soft...basically the pitch
Amplifying Sound using Resonance	Higher pitch is louder
Amplifying Sound using Resonance	A bigger tuning fork is louder

Subsequently, more time was spent providing the students with the appropriate terminology on activities due to the written responses from these activities. Part of the difficulty could be attributed to the timing of the activities. They were the first three activities and for Semester 1 that was the first few days of the school year. However, the misconceptions were not corrected as was seen in the data from posttest question #36 (Figure 6).

Time of Day

Test scores and quarter grades indicate that the time of day had no real effect on these scores (Table 5).

Table 5: Comparison of Scores by Time of Day

Semester 1			**Semester 2**		
Class Hour	Average Test Score	Quarter Grade	Hour	Average Test Score	Quarter Grade
2	67	77	2	67	82
3	71	82	3	60	82
5	62	76	5	67	81
6	69	76	6	63	81
7	60	71	7	67	85
Mean =	66	76.4	Mean =	65	82.2

In looking at the scores on the unit test for Semester 1 the two morning classes, 2nd and 3rd, had relatively close averages. There was a larger gap in the scores between the two afternoon classes, 6th and 7th. The lowest scores were in a midday class, 5th hour, and in an afternoon class, 7th hour. 3rd and 7th hours had the greatest difference from the mean. 3rd hour's scores had the greatest difference above and 7th hour the greatest below the mean.

In comparing the two groups, first and second semester, scores from second semester show that all classes but 3rd varied only 2 points from the mean. However, in 2nd semester 3rd hour was five points below the mean whereas 1st semester they were 4 points above. Therefore, there is no real evidence to support the idea that the time of day had any impact on the final outcome of the students' grades on the unit test and on their quarter grades. However, in comparing the final quarter grades it can be seen that the second semester group had a higher average compared to the first semester group (Table 5) [82.2/76.4]. 3rd hour once again differed, but above the mean this time by six points for the first semester group. But, in the second semester group, 3rd hour's average was equal to the mean. In addition, the largest variation was three points above the mean by seventh hour for the second semester but the greatest deviation below the mean was seventh hour for first semester with 5 points below. Overall the quarter grades for second semester are six percentage points higher but there unit test average was one point lower. Adjusting to the ninth grade, the block schedule, and already having one semester of science are possible reasons behind the higher average.

DISCUSSION

My primary goal in developing this unit on waves was to create a curriculum that would engage students and help them learn. In my opinion, if students are interested and keep engaged while doing science, then they are more likely to learn and want to learn. There are some constraints that I cannot overcome no matter how much the curriculum is altered. First and foremost, like most every teacher, there just is never enough time to teach all the material that I need, let alone want, to teach.

The unit I designed does a nice job covering the required material. However, although it was my intention to do so, I was unable to implement the embedded assessment style that would have benefited more of the students. From the class evaluations and the student opinion polls given at the end of the marking period, the students stated that they liked all the labs but that they had difficulty understanding the material when it came time for the quizzes and tests. Having fun doesn't mean that they are learning the material that the lab intended to teach. The laboratory exercises will need to be revisited with some other forms of assessment during the activity to insure more learning is taking place, possibly the embedded assessment that I described during the introduction. The first three activities will especially need to be changed in hopes of eliminating, as much as possible, the misconceptions noted in Table 4 and in posttest question #36 (Figure 6).

One example of the lack of connection between doing the lab experiment and understanding the objective of the lab is the *Paths of Light and Lines of Sight* lab. It was obvious looking at the student-generated graphs that the data from the 'reflect a view' activity was more closely associated with the line of best fit. Most students, through the class discussion and through answers on their laboratory reports, stated that the real distance was slightly larger than the depth distance instead of that they were equal. When asked, "If you were standing two feet in front of a mirror how far behind the mirror is your reflection?" most students answered correctly, two feet. The activity and the post lab discussion need to be revised to bring together their insight with their observations. They knew the answer but when the data didn't give exact results they discarded their previous knowledge. The students didn't seem to comprehend what is meant by 'mathematical relationship'. Some students had real distances that differed from their depth distances by tenths of a centimeter. If the numbers were 2.1 and 2.2, for example, then the students didn't see these as essentially equivalent and concluded that real distance is not equal to depth distance. I suppose the students are thinking in terms of the math only. The students need to estimate the uncertainty, or accuracy, of the measurement. This same problem was seen when the students were doing their graphs. If the points were not exactly along one straight line they figured they did the entire lab wrong. Explaining a line of best fit was confusing to some students.

One problem is that the opportunity to ask these questions and the time for their spontaneous curiosity needs to be embedded into the class. Possibly setting aside a few minutes each day, or a 'curiosity corner' might meet this need. However, if the students don't have questions there needs to be some activity that constructively utilizes this time. For example, no matter how much planning one does, classroom instruction does not go according to a perfectly set plan. A perfect example is my third hour class, second semester. These students always finished their labs, quizzes, everything, at least ten minutes before the other classes would finish. Third hour is even ten minutes shorter than the classes that meet on Tuesdays and Thursdays. This group had the lowest average on the posttest so I don't believe that finishing early was because they acquired the information more quickly than the other classes.

One factor that isn't evident in the data is the makeup of the class. This third hour class consisted of twenty students. Among these twenty were two students repeating the class for the second time and three more repeating it for the third time. These 'two- and three- timers' definitely had an impact on the dynamics of the class. The 'trivia game' was a way to try to spark some interest in science into the students who continually avoided putting in any effort into their learning and to effectively use any extra time. All five students that failed the course before did so because of the same reason: they wouldn't do their homework or lab reports, which was two-thirds of their grade. Grades in the class are based on three things: tests and quizzes, homework and notebooks, and laboratory experiments and activities. Each of these three areas is equally weighted for one-third of the students' grade.

As a result of teaching this unit I found that there are some techniques that need to be implemented into the unit more often. One is concept mapping to help the students organize their thoughts and to better structure their notes. Through all the confusion of teaching in the math rooms and moving into our 'new' science wing I didn't put the time into teaching the students how to do and use concept maps effectively. I fell into the old way of just writing notes on the board because it took less effort on my part. With the new technology that is being integrated into our school, Power Point could be used for outlines of the daily notes and then as the notes are discussed use concept mapping on the board to help the students see the connections between topics as was my original intention.

A second technique that one of my fellow teachers used as part of her tenure evaluation was to have each quiz cumulative. In this way the students would be better prepared for the big tests at the end of units and for their semester exams. This teacher stated that her overall scores went up by twenty percent. I plan to implement this strategy in the fall in hopes that my students' scores will also improve.

In addition, I would like to revise some of the currently used activities. For example, the percentage of students who stated that frequency, wavelength, and/or amplitude affect the speed of a wave on the posttest was too high [39.5%/23.7%]. After seeing the large number of students that believed that frequency, wavelength, or amplitude affected the wave's speed, I tried to readjust the presentation of this particular material in the beginning of the unit to include statements such as "Speed is not Frequency" (Appendix F-III) in hopes or correcting this misconception. The data show that the percentage of students with the misconception decreased in the 2nd semester group. The data also suggest that the second semester group was more effective in providing the response that I was hoping to see. In addition, in the *Rulers are Noise Makers Too!* activity I plan to do a demonstration of oscillating masses connected by strings in hopes of providing a visual to also help to clarify the speed and frequency issue.

The development of a few more authentic assessments incorporated into the current activities could help to increase the quality of responses on posttest #37. Allowing the students to apply their knowledge to everyday occurrences provides the opportunity for the science to become more meaningful to them. The redesign of the unit from three separate units to one integrated unit provided better transitions from one activity to the next. The integration allowed more lab activities than in the previous structure, which kept the students engaged in science. Since data between years is difficult to compare because of all the variables I am making these statements based on my own opinion. My opinion is based upon the interactions that I observed in the classroom and my own interactions with the students during S-block, during class, and conversations in the halls.

Overall, I am pleased with how the unit played out. The students did learn science as is seen in the comparison of their pre- and posttest data. The majority of students had a basic understanding of the materials at the conclusion of the unit as was also seen in the test data. I would like the students to have a good, solid basis. With all things in life there is always room for improvement. I plan to continue to update, modify, alter, delete, or add each time I teach this unit. I am pleased with the new set up of the curriculum compared to the former structure. I believe that the students were able to see the connections between the concepts of light and sound easier in the modified structure. However, the students I teach are constantly changing and evolving as the world around them changes. The course needs to change and evolve with them. As a teacher it is my duty, my job, and my desire to be the best that I can be which means the course that I teach needs to be the best it can be.

APPENDICES

APPENDIX A-I

UNIT OBJECTIVES: WAVES

- Recognize that waves transfer energy.
- Distinguish between mechanical and electromagnetic wave.
- Explain the relationship between particle motion and wave motion.
- Distinguish between transverse and longitudinal waves.
- Identify the parts of a wave.
- Recognize what factors affect the speed of a wave.
- Solve problems involving wave speed, frequency, and wavelength.
- Solve problems involving wave speed, distance, and time.
- Relate loudness and pitch to properties of sound waves.
- Relate brightness and frequency to properties of light (electromagnetic waves) waves.
- Describe how waves behave.
- Describe how waves reflect.
- Explain why objects appear to be different colors.
- Describe how waves are refracted as they pass between mediums.
- Describe how rainbows are formed.
- Distinguish between constructive and destructive interference.
- Describe the Doppler effect in terms of sound and light.
- Describe how you are able to see.
- Describe how you are able to hear.
- Describe applications of sound and light in everyday life.
- Determine the epicenter of an earthquake using seismic waves.
- Describe the evidence of plate movement.

APPENDIX A-II

MEGOSE OBJECTIVES: WAVES

- C15 --Design and conduct scientific investigations.
- C18 --Recognize and explain the limitations of measurement devices.
- C19 --Gather and synthesize information from books and other sources of information.
- C20 --Discuss topics in groups by being able to restate or summarize what others have said, ask for clarification or elaboration, and take alternative perspectives.
- C21 --Reconstruct previously learned knowledge.
- R8 --Show how common themes of science, mathematics, and technology apply in selected real world contexts.
- R9 --Describe the benefits and risks of new technologies or patterns of human activity.
- R10 --Recognize the contributions made in science by cultures and individuals or diverse backgrounds.
- R12 --Describe some general limitations of scientific knowledge.
- R14 --Discuss the historical development of key concepts and principles.
- PMO8 --Perform measurements and calculations to describe the speed and direction of an object.
- PWV12 --Relate characteristics of sounds that we hear to properties of sound waves.
- PWV13 --Explain how sound recording and reproducing devices work.
- PWV14 --Relate colors to wavelengths of light.
- PWV15 --Explain how we see colors of objects.
- PWV16 –Describe different types of waves and their technological applications.
- PWV17 –Describe waves in terms of their properties (frequency, amplitude, wavelength, wave velocity).
- PWV18 –Describe the behavior of waves when they interact.
- PWV19 –Relate changes in detected frequency of a source to the motion of the source and/or the detector.
- PWV20 –Explain how energy is stored and transformed in vibrating and oscillating objects.

APPENDIX A-III

SEAHOLM BLOCK SCHEDULE

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
1^{ST} 7:25-8:15	T-BLOCK 7:25-8:00 S-BLOCK 8:00-8:40	1^{ST} 7:25-9:00	T-BLOCK 7:25-8:00 S-BLOCK 8:00-8:40	1^{ST} 7:25-9:00
2^{ND} 8:22-9:16				
3^{RD} 9:23-10:13	2^{ND} 8:40-10:20	3^{RD} 9:10-10:40	2^{ND} 8:40-10:20	3^{RD} 9:10-10:40
4^{TH} 10:20-11:10				
5A class 11:17-12:07 5A lunch 12:07-12:52 5B lunch 11:10-11:55 5B class 11:55-12:45	4A class 10:30-12:10 4A lunch 12:10-12:50 4B lunch 10:30-11:10 4B class 11:10-12:50	5A class 10:50-12:20 5A lunch 12:20-1:00 5B lunch 10:50-11:30 5B class 11:30-1:00	4A class 10:30-12:10 4A lunch 12:10-12:50 4B lunch 10:30-11:10 4B class 11:10-12:50	5A class 10:50-12:20 5A lunch 12:20-1:00 5B lunch 10:50-11:30 5B class 11:30-1:00
6^{th} 12:52-1:45	6^{th} 1:00-2:40	7^{th} 1:10-2:40	6^{th} 1:00-2:40	7^{th} 1:10-2:40
7^{th} 1:50-2:40				

APPENDIX A-IV

UNIT CALENDAR

WEEK 1:
Day 1 (50 minute class)
Pretest and student survey

Day 2 (90-100 minute class)
Frequency versus wavelength
Lab: Rulers are noise makers too!

Day 3 (90-100 minute class)
Lab: A Slinky, a slinky....
Drawing waves using record player
Lab: Amplifying sound

WEEK 2:
Day 4 (90-100 minute class)
Lab: Mach 1
$v = d/t$
Lab: What's your Mach?

Day 5 (90-100 minute class)
$v=\lambda f$
Lab: Speed of sound in air

WEEK 3:
Day 6 (50 minute class)
Lab: Doppler Effect
Instrument building

Day 7 (90-100 minute class)
Quiz
Seismic waves
Instrument building

Day 8 (90-100 minute class)
Instrument building

WEEK 4:
Day 9 (50 minute class)
Present sound poems

Day 10 (90-100 minute class)
Media center-instrument building

Day 11 (90-100 minute class)
Quiz: v=d/t and v=λf
Lab: Paths of Light and Lines of Sight

WEEK 5:
Day 11 (50 minute class)
Graphing

Day 12 (90-100 minute class)
What's your angle?
Reflection lab: Plane mirrors
Extra credit: Reflection challenge

Day 13 (90-100 minute class)
Curved mirrors
Refraction: So you say light bends?
Penny in a cup

WEEK 6:
Day 14 (50 minute class)
Present Instrument Projects

Day 15 (90-100 minute class)
Lenses, convex and concave
Lab: Glass vial

Day 16 (90-100 minute class)
Quiz: reflection and refraction
Color- rainbows

WEEK 7:
Day 17 (90-100 minute class)
Interference: constructive and destructive

Day 18 (90-100 minute class)
UNIT TEST

WEEK 8:
Day 19 (50 minute class)
Vision: correcting nearsighted and farsightedness
Microscope Lab
Using Seismic waves- locating epicenter of an earthquake

APPENDIX B-I

Parental/Student Consent Form

Date: August 28, 2000
To: Parents/Guardians/Students
From: Mrs. Brough-Gresh
RE: Collection of data for Master's thesis

For the past four summers, I have been working on my master's degree, at Michigan State University, which focuses on the integration of the physical sciences. This past summer I redesigned the waves section of the Universal Science and Technology A with more laboratory exercises and more authentic applications of the content to every day occurrences. This unit will be approximately eight weeks in length.

In order to evaluate the effectiveness of this unit, I will be collecting pre- and posttest, self-evaluation at the beginning and also at the conclusion of the unit, journal entries, inquiry and reflection questions from the laboratory exercises and student interviews. Also some homework responses may be quoted. This work is required of all students. With your permission, I would like to use data from the above mentioned for my master's thesis. **At no time will any student's name be used in, or connected to the thesis.**

Please fill out the bottom portion of this letter and return it to me by September 1, 2000. I am asking to use your student's data from the waves unit for my thesis. There is no penalty for denying permission to use your data. Your decision will not affect your student's grade in any way. I want to indicate that a withdrawal in no way exempts the student from doing the same work as everyone else; it just means that I will be unable to use his/her data in my thesis. Your privacy will be protected to the maximum extent allowable by law.

Thank you for your time. Please contact the Internal Review Board chairperson David E. Wright (517) 355-2180 for questions about participants' rights as human subjects for research. If you ever have questions or concerns about your student or the class, please contact me (203-3783), for we are a team in your child's education.

Sincerely,

Mrs. Sandra Brough-Gresh

_____ I give Mrs. Brough-Gresh my permission to use my data collected from the waves unit. I understand that Mrs. Brough-Gresh will not use my name and that all student data will remain confidential.

_____ I do not wish for Mrs. Brough-Gresh to use my data in her thesis. I understand that I will not be penalized for choosing to withhold my results.

Student Name (printed) ______________________________

Student Signature ___________________________________ Date________

Parent/Guardian Signature ___________________________ Date________

APPENDIX B-II

STUDENT SURVEY- pre and post

Please rate your understanding for each of the following using the scale below.

- 0 = I have no idea at all.
- 1 = I have heard of it and think I might know something about it.
- 2 = I have a basic understanding of the objective.
- 3 = I have a good, solid understanding of the objective.
- 4 = I could teach it to the class.

1. Design and conduct scientific investigations.	0 1 2 3 4
2. Recognize and explain the limitations of measurement devices.	0 1 2 3 4
3. Show how common themes of science, mathematics, and technology apply in selected real world contexts.	0 1 2 3 4
4. Compare and contrast mechanical and electromagnetic waves.	0 1 2 3 4
5. Explain how energy is stored and transformed in vibrating and oscillating objects.	0 1 2 3 4
6. Describe how waves travel from place to place.	0 1 2 3 4
7. Relate characteristics of sounds we hear to properties of sound waves.	0 1 2 3 4
8. Explain how sound recording and reproducing devices work.	0 1 2 3 4
9. Describe waves in terms of their properties (frequency, amplitude, wavelength, velocity).	0 1 2 3 4
10. Calculate the speed of a wave given the wavelength and frequency.	0 1 2 3 4
11. Relate colors to wavelengths of light.	0 1 2 3 4
12. Explain how we see colors of objects.	0 1 2 3 4
13. Describe different types of waves and their technological applications.	0 1 2 3 4
14. Describe the behavior of waves when they interact.	0 1 2 3 4
15. Relate changes in the detected frequency of a wave to the motion of the source and/or the detector.	0 1 2 3 4

APPENDIX B-III

WAVES UNIT PRETEST

- Please answer each of the following questions as completely as you are able.

    1. What is a wave?
    2. What types of waves exist?
    3. What are the parts of a wave?
    4. What affects the speed of a wave?
    5. How do waves apply to life?
    6. How do you see?
    7. How do you hear?

- Complete a concept map about waves using the following terms: electromagnetic waves, mechanical waves, longitudinal waves, transverse waves, crest, trough, amplitude, compression, rarefaction, and wavelength.

- Complete a Venn Diagram about sound and light.

APPENDIX B-IV

WAVES UNIT POSTTEST

Name ____________________
Hour ______

Multiple Choice—Write the letter of the word or words that best completes the statement or answers the question.
(1 point each)

____ 1. Seismic waves are an example of __ waves.

a. light | b. sound
c. mechanical | d. electromagnetic

____ 2. __ waves can NOT be polarized.

a. transverse | b. light
c. longitudinal | d. ultraviolet light

____ 3. George is sending pulses down a rope at a rate of 2 per second. The distance between pulses is 5 meters. What is the speed of the wave?

a. 2.5 m/s | b. 10 m/s
c. 2 Hz | d. 2.5 Hz

____ 4. The frequency of a light wave determines __.

a. the color | b. how bright it is
c. how fast it is | d. the size of the wave

____ 5. The frequency of a sound wave determines __.

a. the pitch | b. how loud it is
c. how fast it is | d. the size of the wave

____ 6. A yellow shirt looks yellow because it __.

a. reflects red and green light
b. reflects yellow light and absorbs all others
c. absorbs red and green light
d. absorbs yellow light and reflects all others

____ 7. When light moves into a substance of greater density the light is __.

a. bent toward the normal | b. bent away from the normal
c. reflects off the boundary | d. changed into a virtual image

____ 8. Sound waves __.

a. reflect | b. refract
c. diffract | d. all of the above

____ 9. White light separates into different colors when it passes through a prism because of __.

a. differences in wave speed
b. changes in amplitude
c. differences in wavelengths
d. droplets in the air

____10. During a thunderstorm, you see lightning before you hear thunder because __.

a. the thunder occurs after the lightning
b. the thunder is farther away than the lightning
c. sound travels faster than light
d. light travels faster than sound

____11. A train of waves is moving at a speed of 30 m/s. The frequency of the waves is 10 Hz. What is the wavelength?

a. 300 m
b. 30 m
c. 3 m
d. 0.1 m

____12. The frequency of a sound is 500 Hz. A person begins running toward the sound. The frequency the person hears __.

a. stays the same
b. increase
c. decrease
d. stop

____13. Sound travels fastest in __.

a. air
b. water
c. warm water
d. glass

____14. This type of electromagnetic waves has slightly longer wavelengths as compared to red light.

a. yellow light
b. ultraviolet light
c. infrared light
d. green light

____15. Light can be modeled as __.

a. an electromagnetic wave
b. a stream of particles called photons
c. rays that can travel in a straight line
d. all of the above

____16. A flat mirror forms an image that is __.

a. virtual
b. smaller than the object
c. real
d. larger than the object

____17. Which of the following wavelengths of visible light bends the most when passing through a prism?

a. red
b. yellow
c. green
d. violet

Fill-in-the-Blank- -Write the word or words in the blank provided to best completes the following statements. (1 point each)

18. The greater the ______________________ of a sound wave, the louder the sound.

19. The bending of waves as they pass from one medium to another is ______________.

20. The imaginary line perpendicular (90 degrees) to a surface where light hits a mirror is called the ___________________.

21. The law of reflection states that the angle of incidence is equal to the angle of ____________________.

22.The primary colors of light are _________, __________, and ___________.

23. When the energy of two waves adds together momentarily it is called ___________________ interference.

24. ______________ mirrors cause light rays to diverge.

TRUE/FALSE--Write a T in the blank if the statement is TRUE. If the statement is FALSE, correct the underlined word and write it in the blank. (1 point each)

_________________ 25. The energy of a wave depends on the <u>amplitude</u> of the wave.

_________________ 26. As the frequency of a wave increases, the <u>wavelength</u> increases.

_________________ 27. A(n) <u>electromagnetic</u> wave consists of changing electric and magnetic fields.

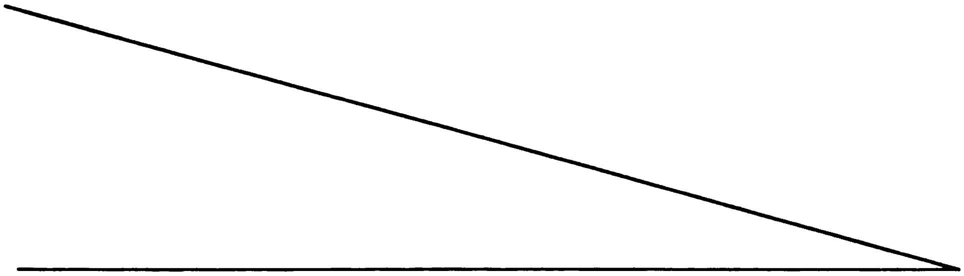
_________________ 28. <u>Reflection</u> is the bouncing back of a wave as it meets a surface or boundary.

_________________ 29. According to the Doppler effect, light from a star moving away from the Earth will have a <u>higher</u> frequency then light from a star moving towards the Earth.

_________________ 30. The area of a sound wave where the molecules are closest together is called the <u>refraction</u>.

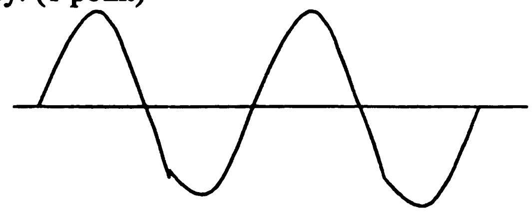
PERFORMANCE OBJECTIVES

31. Measure the following angle to a tenth of a degree.
(1 point)



32. Measure the width ⟷ of this test paper. ____________ cm (1 point)

33. Draw a wave with twice the amplitude of the wave below but with the same frequency. (1 point)



34. Answer the following using the diagram on the right. (3 points)

A= ______________

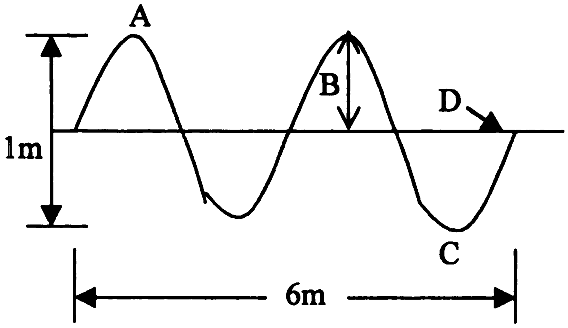
B= ______________

C= ______________

D= ______________

One wavelength = ______ m

Amplitude = _______ m



SHORT RESPONSE—Answer the following in complete sentences. (3 points each)

35. What is a wave? (What determines how and where a wave can travel?)

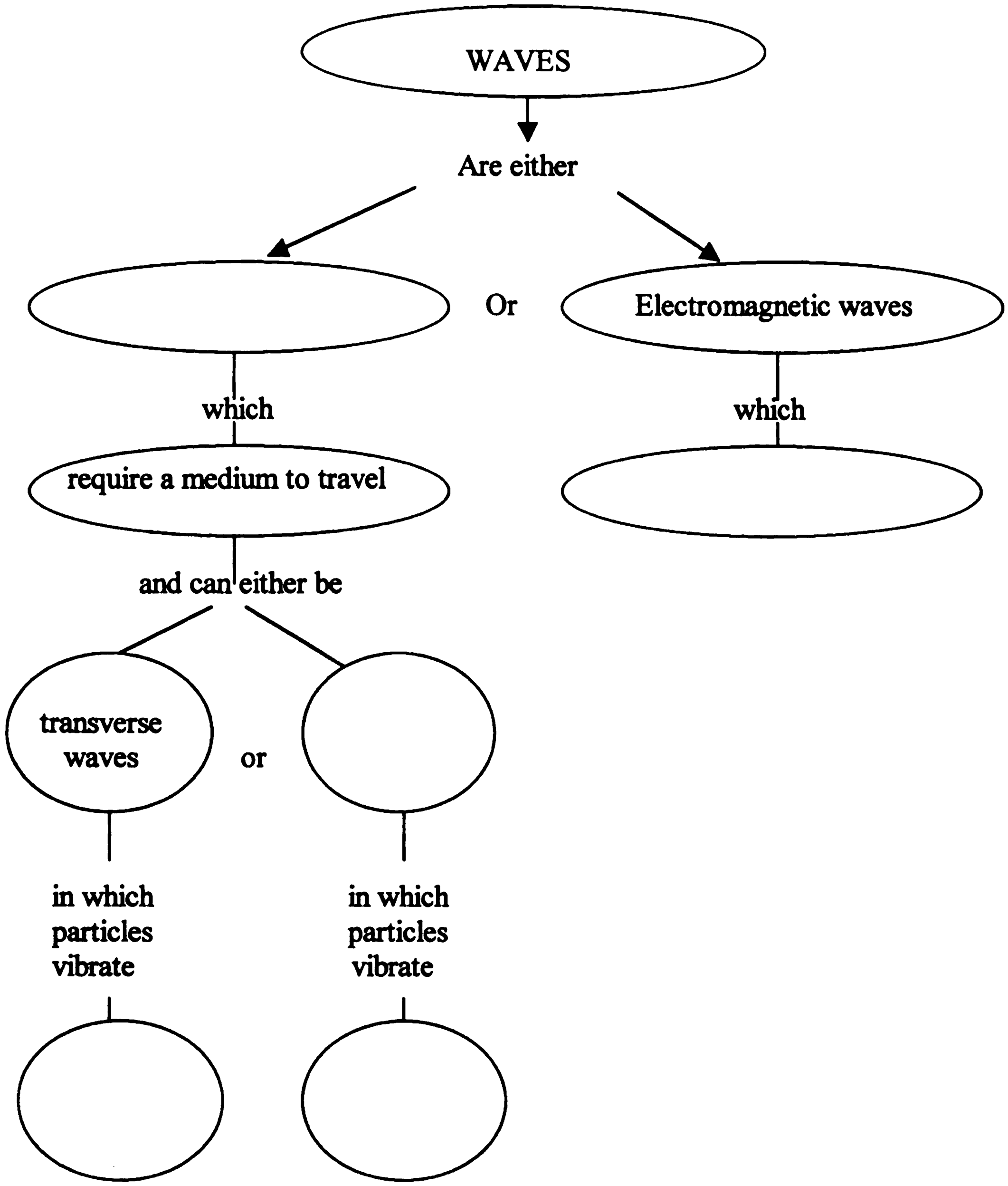
36. What affects the speed of a wave?

37. How do waves apply to life? (What are some applications of waves in everyday life?—Be specific and explain.)

DIAGRAMS-

38. Complete a Venn Diagram about light and sound.
(4 points)

39. Complete the following concept map. (3 points)



APPENDIX C-I

Wave Album Project

A Waves Collection

- Make a collection of 20 pictures of different examples of waves.
- Look through magazines, catalogs, and newspapers for examples.
- You can use up to 3 original drawings.
- Cut out examples for your collection, put each picture on a page and classify it as either transverse or longitudinal and as mechanical or electromagnetic.
- Mark the wavelength on your picture with a ruler and a pen if it is visible.
- Be sure your collection is neat and in a folder or notebook.
- Include a title page or cover.
- The last page of your album is to be a written reflection and should include:
  - A statement of how the waves are related to one another.
  - A diagram or chart categorizing the waves that need a medium to travel and those which do not.
  - Your thoughts on this project.
- DUE AT END OF MARKING PERIOD

*Adapted from "Glencoe Physical Science" (Performance Assessment), McLaughlin/Thompson, 1999. p. 11.

APPENDIX C-II

Instrument Building 101

This is a group project. Group size will depend on the class size. Groups will be decided on by the luck of the draw. You will be given one week of class to build and research. One day will be designated as Media Center Day. Each day of class will contain a "Science Commercial" for approximately 15-20 minutes to cover some miscellaneous topics in waves. You also have S & T block time available to you. Projects will be presented in class.

Requirements:

- To design, build, and demonstrate an instrument. (5 points)
    - You must be able to alter the volume. (3 points)
    - You must be able to alter the frequency using at least two different methods. (4 points)
    - You must be creative. (4 points)
- To describe how a sound recording or reproducing device works. (9 points)
    - Examples include but are not limited to:
        - Tape recorders, medical ultrasound devices, hearing aids, laser disk players, CD players.
    - Make sure to give credit to the source by which you acquired the information.
- To work as a team. (10 points)
    - You must involve everyone in the group.
        - You have the freedom to do this as the group decides, but you must have a journal to record your progress and individual duties.

Use your time wisely.

HINTS:

- Keep it small so that it can be easily transported, like in a shoe box.
- Exchange phone numbers or e-mail so that your group members can contact each other.
- Divide up the duties to save on time, i.e. secretary/typist, researcher, builder, designer, presenter, poster maker, etc....

APPENDIX D-I

Rulers are Noise Makers Too!

Mini Lab – Wavelength versus Frequency

Problem: How does the length of a vibrating object affect the frequency of a sound?

Hypothesis:

Procedure:

1. Hold the ruler on the table with the majority of the ruler sticking out from the table.
2. Flick the loose end of the ruler, observe the vibrations, and listen to the sound produced. Record your observations.
3. Shorten the amount of ruler extending out from the table and repeat step 2.
4. Continue to adjust the length of the ruler while observing the vibrations and listening to the sound produced. Record your observations.

Observations:

Analysis:

1. What happens to the length of one vibration as the ruler shortens?
2. What happens to the sound produced as the ruler shortens?
3. What is the relationship between the length of one vibration and the sound produced?

APPENDIX D-II

A slinky, a slinky, a wonderful observational,demonstrational toy

Goal: To observe the characteristics of transverse and longitudinal waves

Pre Lab: define transverse wave, longitudinal wave, amplitude, frequency, and wavelength

Procedure (Part A):

1. Using a slinky make a transverse wave.
2. Change the amplitude. Record your observations.
3. Increase the frequency. Observe the wavelength and record your observations.
4. Decrease the frequency. Observe the wavelength and record your observations.

Procedure (Part B):

5. Using a slinky make a longitudinal wave.
6. Change the amplitude. Record your observations.
7. Increase the frequency. Observe the wavelength and record your observations.
8. Decrease the frequency. Observe the wavelength and record your observations.

Observations:

Analysis:

1. Which type of wave was easier to observe and why?
2. What part of the wave was affected by an increase in your energy input? EXPLAIN.
3. Does a change in amplitude affect the wavelength? The frequency?
4. What happens to the frequency of a wave when the wavelength decreases?
5. Does the speed of the wave change? EXPLAIN

Extension (Hypothesis):

- Observe a transverse wave pulse made in a spring and a slinky simultaneously. Why does the wave pulse in the spring travel much faster than in the slinky?

APPENDIX D-III

Amplifying Sound using Resonance

Pre lab/Post lab Questions:

1. How is sound produced?
2. What determines the frequency of a sound?
3. What part of the sound wave shows the volume?

Problem: How you can amplify the sound of a tuning fork?

Hypothesis: (Write your best educated guess to the problem, in other words, a good answer to the question.)

Materials:

Tuning fork
Rubber mallet or tennis shoe sole

Procedure:

1. Strike the tuning fork with the rubber mallet or against the sole of your shoe.
2. Touch the base of the tuning fork to objects around the room. Listen to the sound from the tuning fork. Record your observations.

Observations: (Record any observations.)

Analysis: (Answer the questions in complete sentences.)

1. What do you notice about the sound from the tuning fork if you strike it harder?

2. What types of objects helped amplify the sound of the tuning fork in step 2?

Conclusion: (Your hypothesis is clearly stated. Describe what you can derive from your observations and the support you have for this. Make connections to everyday life. List any questions that you've encountered as a result of this laboratory exercise.)

APPENDIX D-IV

Mach 1-Speed of Sound

Pre lab/Post lab Questions:

1. What is the speed of sound?
2. What state of matter does sound travel fastest in?

Problem: What is the speed of sound in air?

Hypothesis:

Materials:

2 boards
Stopwatch
Football field (or any known distance)

Procedure:

1. Have one person on a goal line with two boards.
2. Have a second person stand on the opposite goal line with a stopwatch.
3. Have the person with the boards hit them against each other and the person with the stopwatch to start timing when they see the boards hit.
4. Stop timing when you hear the sound. Record.
5. Repeat two more times.
6. Calculate the speed of the sound using $v = d \div t$.
7. Calculate the average speed of sound for your class.
8. Record the average speed of sound for all classes.
9. Calculate the percent error for each class.

HINT: The football field is 100 yards from goal line to goal line. 1 yard = 0.9144 meters

Data Table: (Holds measured or observed data and is organized, neat, with labels and units.)

Results Table: (Holds calculated values and is organized, neat, with labels and units.)

Analysis:

1. How do you account for your error? Is it acceptable?
2. What might change the speed of the sound on an hour to hour or day to day basis?
3. How would you calculate the speed of sound in water?

APPENDIX D-V

What's your Mach?

Purpose: To calculate the speed of a person and to compare the person's speed to the speed of sound.

Procedure:

1. Mark off a known distance.
2. Time one person running that distance.
3. Repeat step 2 twice more.
4. Average the three trials.
5. Calculate the person's average speed.

Analysis:

1. What is the ratio of the speed of sound to the person's speed?
2. What is the ratio of the speed of light to the speed of sound?
3. EXTRA CREDIT POINT: What would this person's Mach speed be?

Data Table:

Results:

Conclusion:

APPENDIX D-VI

The Doppler Effect

Problem: How and why does the sound of a moving object change as it passes you?

Hypothesis:

Materials:

Sound source (smoke detector beeper)

Procedure:

1. Gently toss the sound source around the room and note what happens to the sound.

Analysis:

1. What happens to the sound you hear as it is moving away from you?
2. What happens to the sound you hear as it is moving towards you?

Extension:

If you watch the local weather forecast you may have noticed that they use Doppler radar. Radar sweeps horizontally, giving information on the location, intensity, and direction of a storm's movement. Radar can also sweep vertically, giving information on cloud height and the altitude at which snow and ice are melting. Doppler radar uses microwaves as opposed to radio signals or sound waves. (Remember sound waves and radio waves are NOT the same thing.)

This is basically how it works. A Doppler radar signal is sent out, intercepted, and returned to the station. The pitch and of course the wavelength is received different than the original signal. If the signal comes back with a higher frequency, the object is approaching. If the signal returns at a lower frequency the object is moving away from the station. The signals are analyzed to determine the location, movement, and speed of the object. With Doppler radar the objects it locates are storms. The same principle is applied when police monitor for speeding drivers. Doctors also use it to monitor blood flow during an ultrasound.

APPENDIX D-VII

Paths of Light and Lines of Sight
Real Distance versus Depth Distance

Background Info: Light is a form of energy that travels in a straight line. All waves travel in a straight line until they meet some type of barrier. The waves could reflect, refract, or diffract. There are two basic categories of visible light: incident light and reflected light.

Pre Lab:

- Define: *real distance, depth distance, dependent variable, independent variable*

Problem: How far into a mirror is an object's reflection?

Materials:

Mirror	Red Reflect-A-View
Mirror brackets	Pin in a cork or piece of clay
Ruler	Scrap piece of paper (8½ x 11)

Procedure:

1. Place your mirror on the table about 15 cm in front of you with the reflective side facing you and the piece of paper up against the back of the mirror.
2. Place the pin in front of the mirror, about 10 cm away.
3. Look in the mirror and mark with your pencil on the paper where you perceive the image of the pin to be located.
4. Record your real and depth distance in a data table to a hundredth of a centimeter.
5. Repeat until you have completed four trials with different real distances.
6. Construct a line graph of your data. You must decide what are your dependent and independent variables. Your graph must have a title, labels on the axis, units, and a line of best fit.
7. Repeat the entire lab but now use the Red Reflect-A-View.

Observations:

Data Table:

Analysis:

1. What is the relationship between the real distance and the depth distance?
2. Did the mirror or the Reflect-A –View give you more accurate data? EXPLAIN
3. Should your line of best fit go through the origin? WHY or WHY NOT?
4. Why don't all the points lie on your line?

Conclusion:

APPENDIX D-VIII

Reflection Challenge

So how many are there?

Purpose: To test your understanding of science and math.

Materials:

- Two Mirrors
- Mirror brackets
- Protractor
- Pin in a cork or piece of clay

Procedure:

1. Arrange two mirrors so that they are 180° to one another (side by side).
2. Place the pin between the mirrors. You should see two pins, the original and one reflection.
3. Place the mirrors at 90° to each other and place the pin between the two mirrors. Observe the number of pins seen. (Count the original and all the complete reflections.)
4. Repeat placing the mirrors at 60°, 45°, 30° and parallel to one another. Record the number of pins each time.

Data Table: (Construct a data table)

Analysis:

1. What is the mathematical relationship between the angle of the mirrors and the number of pins?

APPENDIX D-IX

Refraction-Penny in a Cup

Pre lab/Post lab questions:

1. What affects the speed of waves?
2. What is the relationship between the angle of incidence and angle of refraction?

Problem: How does water bend light?

Hypothesis: (What is your best answer to the question?)

Materials:

Dixie cup
Penny
Water

Procedure:

1. Place a penny at the bottom of a short, opaque cup.
2. Slide the cup slowly away from you until you can no longer see the penny.
3. Without disturbing the penny, have your partner SLOWLY pour water into the cup until you can see the penny.
4. Repeat the lab until all group members have observed the "movement" of the penny.

Observations:

Analysis:

1. Did the penny itself actually move? Explain how you were able to see the penny after the water was in the cup.
2. Sketch the light path from the penny to your eye before the water was added to the cup.
3. Sketch the light path from the penny to your eye after the water was added.

Conclusion:

APPENDIX D-X

Glass Vial Lab- a convex lens experience

Pre lab/ Post lab questions:

1. What affects the speed of light?
2. What kinds of images are seen through convex lenses?

Problem: How does the location of a lens affect the observed image?

Hypothesis:

Materials:

Sealed glass vial filled with water
3 x 5 card with SULFUR DIOXIDE printed in red and blue

Procedure:

1. Place the vial on the card and arrange the vial so it is parallel with SULFUR DIOXIDE. Observe the words through the vial. Record your observations.
2. Hold the tube 1 cm over the card, keeping it parallel to the words and record your observations.
3. Repeat step 3, holding the tube at several other heights above the words and record your observations.
4. Hold the vial perpendicular to the words and observe them through the vial and record your observations.

Observations:

Analysis:

1. How do you explain the different observations as the vial is lifted off of the card?
2. Are the images seen at these heights real or virtual?
3. What everyday object would give the same results as this little glass vial?
4. Why do the individual letters appear differently when the tube is parallel and when it is perpendicular?

Conclusion: (Your hypothesis is clearly stated. Describe what you can derive from your observations and the support you have for this. Make connections to everyday life.)

APPENDIX D-XI

Biology Connection-The Optics of Microscopes

Pre lab/Post lab questions:

1. What happens to light as it passes into a denser medium?
2. How are the refracted rays from a convex and a concave lens different?

Purpose: Apply rules of convex and concave lenses to understand the physics of a microscope.

Materials:

Microscope
Magazine cuttings

Procedure:

1. Cut out a lowercase 'e' from one of the magazine clippings.
2. Place the clipping on the stage of the microscope so that the 'e' is right side up.
3. Put the 10x objective into place and bring the image into focus. (Make sure to use the course adjustment first and then the fine adjustment.)
4. Look at the image of the 'e'. Compare the image of the 'e' to the actual 'e' on the stage. Record your observations.
5. Repeat steps 2-4 with a capital 'I' and a 'O'. Record your observations.
6. Using any clipping, move the object to your left while looking through the microscope. Record your observations.
7. Move the clipping away from you (up) while looking through the microscope. Record your observations.

Observations:

Analysis:

1. How much larger is the image as compared to the object?
2. How does the image of 'e' appear as compared to the actual 'e' in step 4?
3. What happens when you put the 'I' under the scope? The 'O'? Explain.
4. How do your observations from steps 6 & 7 relate to your observations from steps 4 & 5?
5. Does a microscope have convex or concave lenses? Explain.

Extension:

1. Place several different clippings under the microscope.
2. Observe the colors that are seen through the scope as compared to the colors that the naked eye can see from the clipping. Explain your observations.

Conclusion:

APPENDIX E-I

Drawing Waves

- Draw a sound wave that has a wavelength of 6 cm and an amplitude of 1 cm. *(Remember sound waves are not transverse waves, even though we draw them as such so that we can easily see their characteristics.)* This wave will be your reference wave for each step below.

1. Using your reference wave keep everything the same except increase the amplitude.

    - *How would the sound from this wave compare to the sound that would be produced from your reference wave?*

2. Using your reference wave keep everything the same except this time decrease the wavelength.

    - *What happened to the frequency?*

APPENDIX E-II

$v = d \div t$

velocity (speed) = distance ÷ time

- The unit for distance is meters (m)
- The unit for time is seconds (s)
- The unit for speed is therefore meters per second (m/s)

Make sure to show the formula, substitution, and units on your answer. ****Remember the speed of a wave is determined by how far the wave travels in a given amount of time.***

1. Thunder is heard 2 seconds after the lightning bolt is seen 680 meters away. What is the speed of the sound?

2. You see the batter strike the ball, but here the sound 1.4 seconds later. You are 476 meters away. How fast is the sound?

3. If the speed of sound in air is 340 m/s and you are 200 meters from the starting line of a race, how long after you see the smoke will you hear the sound of the starter's pistol?

4. You are walking along and you see an accident. You hear the crash 1.2 seconds after you see it. The speed of sound in air is 340 m/s. How far were you from the scene?

5. You decide to test the laws of science at "Echo Point". The cliff wall is (0.5 km) 500 meters away. Knowing the speed of sound in air, how long does it take for your clever utterance to return to you? How long did it take for your voice to get to the cliff wall in the first place?

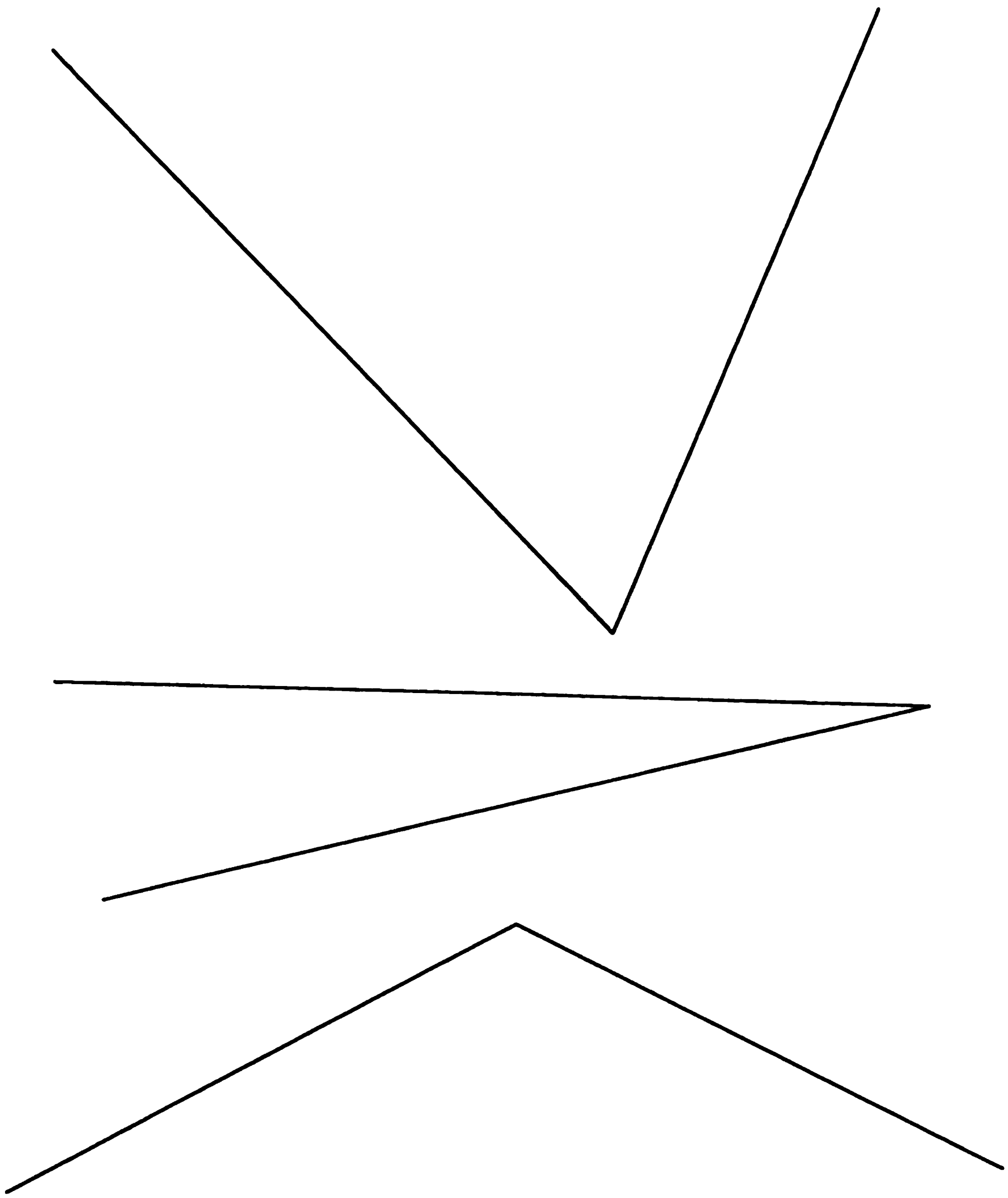
6. The speed of sound in water is 1.5 km/s (1500 m/s). A submarine sends out an active sonar signal and hears the return ping in 0.04 seconds. How far away is the "obstacle" from the submarine?

7. A charter boat uses a depth finder to locate reefs. If the beep takes 0.02 to reach the reef, how deep is the reef? (Remember the speed of sound in water is 1500 m/s)

APPENDIX E-III

What's your angle?

- Measure the following angles to one place smaller than the last division. *(With most protractors that is the tenths place.)*



APPENDIX E-IV

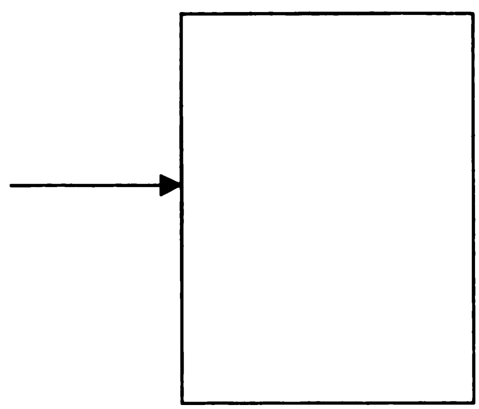
So you say that light "bends"?

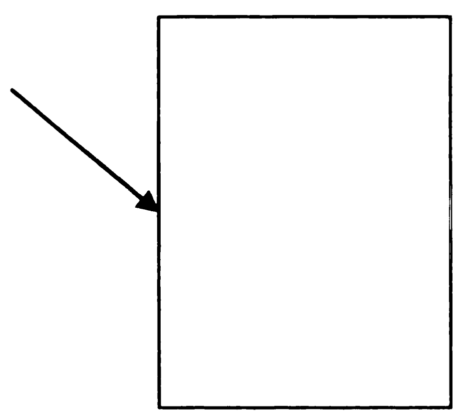
Background Info: Refraction is the process by which waves change direction due to a change in the wave's speed. The change in speed is caused by a difference in density as the wave travels from one medium to another.

- Light slows down when it enters a substance of higher density.
- Sound will speed up when it enters a denser substance.

Predict what the refracted ray would look like in each of the following and then test them using the LIGHT BOX and the card with the narrow single slit and draw

PREDICTION ACTUAL





APPENDIX F-I

NOTES: Wavelength, frequency

Sound-
Produced by vibrating objects

Waves-
The energy of a wave is seen in the amplitude
For sound the energy determines the volume
For light the energy determines the brightness
For earthquakes the energy determines the shaking

Wavelength-
Distance between two consecutive (corresponding) points on a wave
Symbol for wavelength is λ (lambda)
Measured in meters (m)

Frequency-
Number of vibrations (waves) per second
Symbol for frequency is f
Measured in Hertz (Hz)

Amplitude-
Shows the amount of the disturbance
Measured from the equilibrium to the crest or from the equilibrium to the trough

APPENDIX F-II

NOTES: Electromagnetic waves versus Mechanical waves

Waves-
Transmit energy through matter or space

-limited by where they can travel:

Mechanical waves: waves that are produced by vibrating objects and can only travel in matter

Ex: sound, water, seismic

Electromagnetic waves: waves that are produced by moving electrical charges and can travel in matter or space

Ex: light, radio, x-rays, gamma rays, microwaves, ultraviolet light, infrared

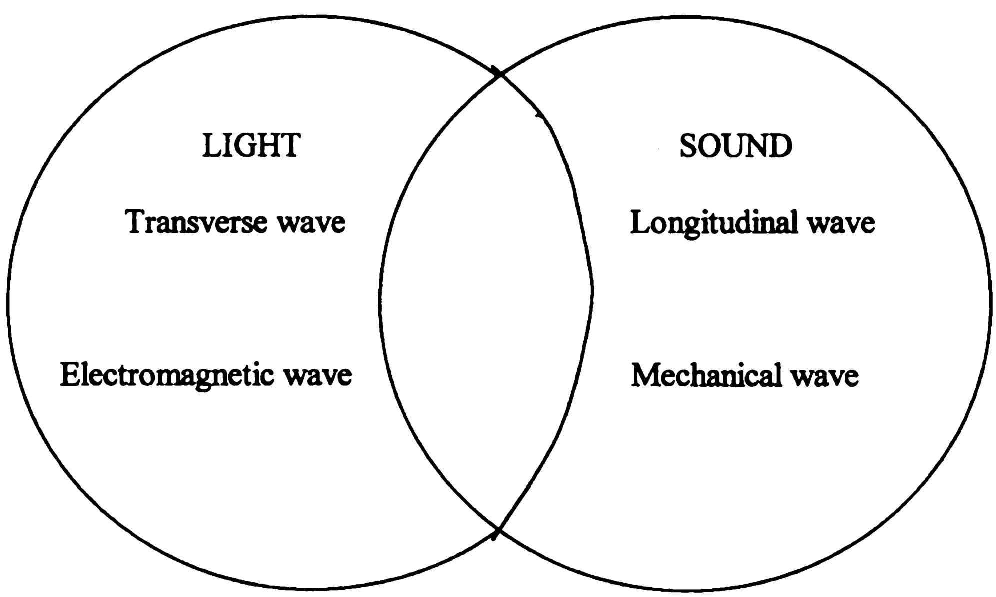
-described by how they travel

Longitudinal (compressional): particles in the wave move parallel to the direction the energy is traveling

Ex: sound, primary (P) seismic waves

Transverse: particles in the wave move perpendicular to the direction the energy is traveling

Ex: light, secondary (S) seismic waves



APPENDIX F-III

NOTES: Speed

*The amplitude of a wave can change without changing the frequency or wavelength of a wave.

The speed of a wave is determined by the density of the medium in which the wave is traveling and the temperature of the medium

-Mechanical waves can travel the fastest in denser matter (solids).

-Electromagnetic waves can travel the fastest in the absence of matter (space).

SPEED IS NOT FREQUENCY

Speed is how fast the wave travels from one place to another.

Frequency is how often waves (oscillations) occur.

Speed (velocity) equals Distance Traveled divided by Time

$$\underset{(m/s)}{v} = \underset{(m)}{d} / \underset{(s)}{t}$$

Speed (velocity) also equals wavelength times frequency

$$\underset{(m/s)}{v} = \underset{(m)}{\lambda}\,\underset{(Hz)}{f}$$

APPENDIX F-IV

NOTES: Range of perception

Speed of sound-

In air sound travels at 330 m/s or 760 mph or Mach 1
In water sound travels approximately 1500 m/s
In solids the speed of sound varies with the solid

Speed is equal to the distance the wave travels in the amount of time needed to cover that distance.

$v = d/t$
Speed is measured in meters per second (m/s).
Distance is measured in meters (m).
Time is measured in seconds (s).

Range of perception

-Humans can only hear a limited range of frequencies (20-20 000 Hz)- audible range
-Infrasounds are below (lower) then range for human hearing
-Ultrasounds are above (higher) the range of human hearing

These prefixes infra- and ultra- have the same meaning when used with light.

Visible light is the range of frequencies that humans can see.
Infrared light is just below the range that humans can see and ultraviolet is just above.

NOTES: Rainbows and color

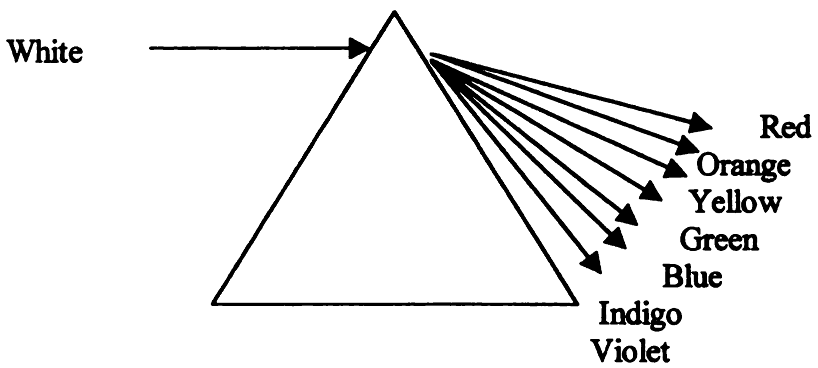
Rainbows-

-Formed by light being refracted as it passes through a more dense medium. As visible light travels through a more dense medium it slows down, as it slows down the wave bends. Each color in the visible spectrum has its own frequency and wavelength. The wavelength of the wave determines the angle at which the light bends, refracts. As a result, the colors (red, orange, yellow, green, blue, indigo, and violet = Roy G. Biv) all bend at different angles and separate to form the visible spectrum... a rainbow.

Red light has the longest wavelength of the visible spectrum followed by orange, yellow, green, blue, indigo, and violet has the shortest wavelength. Therefore, red bends the least and violet bends the most and you get a rainbow.

- White light is all colors.
- Black light is the absence of color.

    - A red shirt appears red because it reflects red light and absorbs everything else. You stay cooler wearing white clothing in the summer because white reflects all colors of light and therefore reflects the energy of those colors. Black clothing absorbs all colors of light therefore absorbing more energy and you get warmer because that energy is converted to heat.



APPENDIX F-VI

NOTES: Electromagnetic spectrum

Electromagnetic Spectrum

- A specific range of frequencies produced by moving electric charges that induce magnetic fields. These waves are all classified as electromagnetic waves.
- EX: radio waves, microwaves, infrared light, visible light, ultraviolet light, x-rays, and gamma rays
    - -The term LIGHT is often used to mean all electromagnetic waves and not just visible light
        - "Light" or electromagnetic waves all travel at the same speed.
        - THE SPEED OF LIGHT = 3×10^8 m/s or 186,000 miles/sec

Visible light is in the 400 – 700 nm range

- Microwaves, radio waves, and infrared light have wavelengths greater than visible light.
    - (REMEMBER-as wavelength increases frequency decreases. That means that microwaves, radio waves and infrared light have frequencies below or less than visible light)
- Ultraviolet, x-rays, and gamma rays have wavelengths that are shorter than visible light, and as a result have higher frequencies than visible light.

APPENDIX F-VII

NOTES: Doppler Effect

Doppler Effect

-An apparent change in frequency due to movement of the source or the observer.

-With sound this apparent change in frequency is heard as a change in pitch

-With light this apparent change in frequency is seen as a change in color or the classification of light

As a source of sound approaches you the waves reach you closer and closer together which you interpret as a shorter wavelength and a higher frequency. The same thing happens if you are approaching a stationary source of sound.

As the source moves away from you the waves reach you farther and farther apart which you interpret as a longer wavelength and a lower frequency.

APPENDIX F-VIII

NOTES: Depth distance versus Real distance

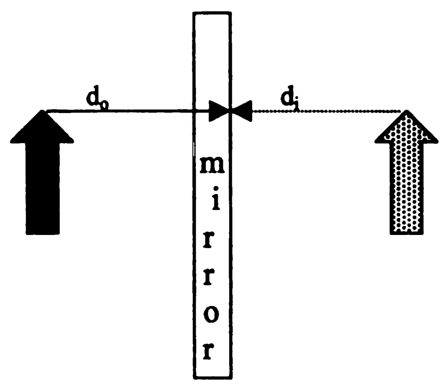
The image seen inside a plane mirror is the same distance behind the mirror that the object is in front a plane mirror.

REAL DISTANCE (d_o) = DEPTH DISTANCE (d_i)

-The Real Distance (d_o) is the distance from the object to the reflective surface of the mirror.

-The Depth Distance (d_i) is the distance the image is from the reflective surface of the mirror.

**This law also applies for curved mirrors however you must remember that the real distance for an object changes as the curve of the mirror changes. The depth distance changes as a result of the real distance changing so the Depth Distance will continue to be equal to the Real Distance.



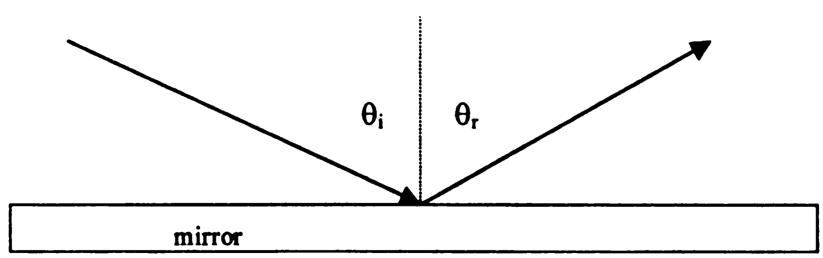
- The solid arrow represents the object.
- The shaded arrow represents the image.
- Solid lines represent paths of light.
- Dotted lines represent lines of sight.

APPENDIX F-IX

NOTES: Law of Reflection

Reflection

- Occurs when energy hits a barrier or more dense medium and bounces off.
- This energy always bounces off the barrier at an angle equal to the angle of contact.
  - The LAW OF REFLECTION: angle of incidence is equal to the angle of reflection
    - The angle of incidence (θ_i) is measured between the incident ray and the normal.
    - The angle of reflection (θ_r) is measured between the reflected ray and the normal.
    - The normal is an imaginary line at 90^0 to the surface at the point where the energy hits the barrier. It is drawn as a dotted line.



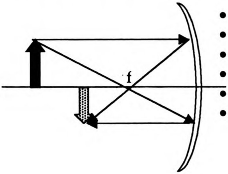
APPENDIX F-X

NOTES: Curved Mirrors

Concave Mirrors-

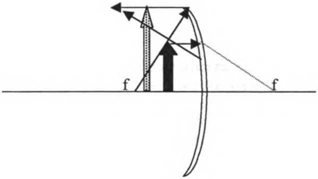
-Cause light rays to converge

-Objects outside the focal point appear upside down



- Solid lines represent paths of light
- Dotted lines represent lines of sight
- Images appear where reflected rays cross
- Solid arrows represent objects
- Shaded arrows represent images
- 'f' represents the focal point

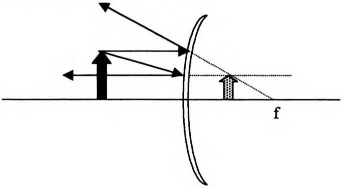
-Objects inside the focal point appear right side up and larger



Convex Mirrors-

-Cause light rays to diverge

-Objects appear smaller and right side up



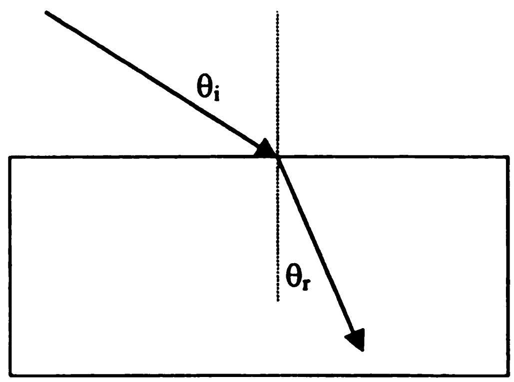
APPENDIX F-XI

NOTES: Refraction

Refraction-

The bending of a wave due to a change in wave speed caused by the wave traveling into a substance of different density

- Sound will travel faster when it travels into a substance of greater density.
- Light will travel slower when it travels into a substance of greater density.



The diagram above shows a light ray traveling from air into glass (or any medium more dense than air). The light ray bends, or changes direction as it slows down when it travels into the more dense glass. The angle of incidence is therefore greater than the angle of refraction. If the wave had increased its speed, like when the light goes from the glass back into air, the angle of refraction would be greater than the angle of incidence.

- The 'normal' is an imaginary line drawn at 90^0 to the surface where the light ray hits as a dotted line.
- The angle of incidence (θ_i) is measured between incident ray and the normal.
    - The angle of refraction (θ_r) is measured between the refracted ray and the normal.

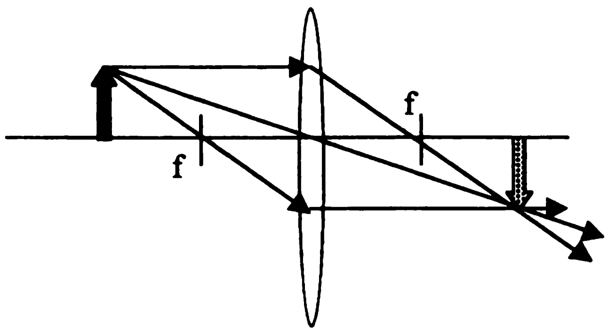
APPENDIX F-XII

NOTES: Lenses

Convex Lenses-

-Cause light rays to converge

-Objects outside the focal point appear upside down



- Solid lines represent paths of light
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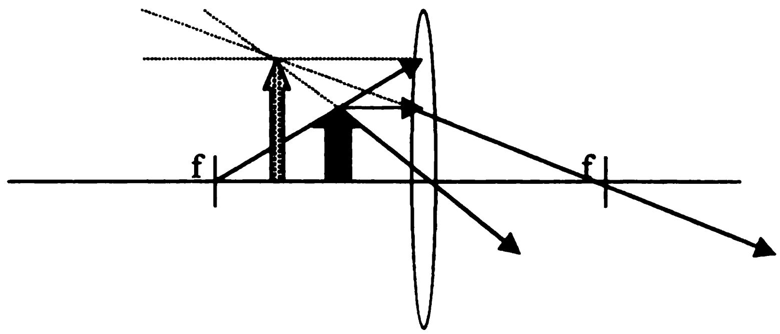
- Shaded arrows represent images
- 'f' represents the focal point

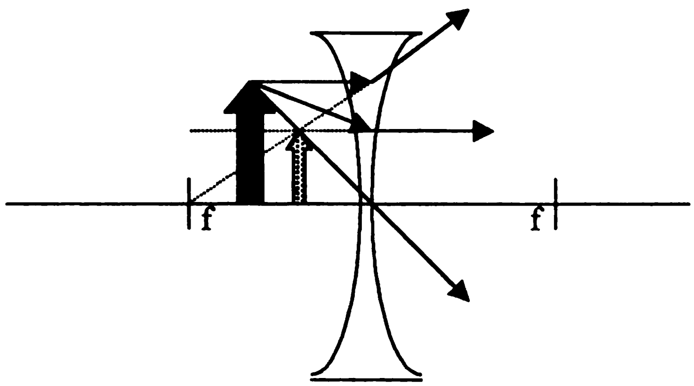
-Objects inside the focal point appear right side up and larger



Concave Lenses-

-Cause light rays to diverge

-Objects appear smaller and right side up



APPENDIX G-I

Individual Pre-Survey Responses - Semester 1															
	Survey Question														
Student	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**	**#15**
1	1	1	1	0	1	1	0	0	0	0	1	0	0	0	0
2	2	0	1	1	1	0	1	1	0	0	1	3	0	1	0
3	3	3	2	1	0	1	2	1	2	0	1	2	2	1	0
4	1	2	3	2	2	2	1	3	1	2	0	1	2	1	2
5	2	2	3	1	0	1	1	3	0	0	0	0	0	0	1
6	1		0	1	0	1	0	1	0	0	0	1	0	0	0
7	3	3	3	1	2	1	1	1	1	1	2	1	1	1	1
8	2	3	2	3	3	3	2	0	0	0	0	4	2	0	1
9	2	2	1	0	0	1	2	1	0	0	0	0	1	1	0
10	2	1	2	2	2	0	1	0	0	0	1	2	0	0	1
11	1	1	1	0	2	2	2	3	0	1	0	0	0	0	1
12	0	0	2	0	0	1	0	0	0	0	0	1	0	0	0
13	2	1	2	1	0	1	0	2	1	0	2	2	0	0	0
14	2	1	2	1	1	2	1	0	1	1	2	3	1	0	1
15	1	1	1	0	0	1	0	0	0	0	1	0	0	0	0
16	2	2	2	1	1	2	0	0	0	1	0	1	0	1	0
17	2	2	2	1	1	1	1	0	0	0	0	1	0	0	0
18	2	1	2	1	2	1	0	0	0	0	0	1	0	0	0
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20	3	1	2	1	0	2	1	2	1	0	0	1	0	1	0
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24	2	1	2	0	0	0	2	0	0	0	1	3	0	0	0
25	2	2	2	0	0	1	0	0	0	0	0	1	2	0	0
26	2	2	3	1	1	1	1	1	1	1	1	0	1	0	0
27	3	3	3	1	1	1	0	0	0	0	2	2	1	1	1
28	1	1	2	0	0	0	0	0	1	0	1	2	0	0	0
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	3	3	4	3	3	3	3	4	3	2	2	3	3	2	2
31	3	3	3	3	3	3	3	2	3	1	4	2	2	2	2
32	0	0	3	0	0	2	0	1	0	2	0	0	0	4	0
33	2	2	2	1	0	1	2	0	1	1	2	2	1	1	1
34	2	3	1	0	2	1	0	0	0	0	1	0	1	0	0
35	2	2	1	0	1	1	1	1	1	0	0	3	2	1	1
36	3	2	3	0	1	2	0	2	0	1	2	3	2	2	1
37	1	2	2	0	0	1	2	1	0	0	2	3	1	0	0

38	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2
39	2	2	1	0	0	1	0	0	0	0	0	0	0	0	0
40	1	1	2	2	2	3	2	3	2	1	2	3	2	0	1
41	2	2	2	1	3	1	1	1	2	0	3	3	1	1	0
42	3	2	1	0	3	1	0	1	2	0	0	2	0	1	1
43	3	3	2	3	2	3	2	0	2	3	2	1	0	1	1
44	3	1	2	1	1	2	2	2	1	0	2	2	0	1	1
45	3	2	2	2	1	3	2	2	2	1	3	3	2	2	2
46	3	2	2	1	2	0	1	2	1	0	0	0	0	1	1
47	1	0	3	0	0	0	0	3	0	0	0	0	0	0	0
48	2	0	2	0	1	1	2	0	1	0	1	2	1	1	0
49	2	2	3	1	1	2	2	1	0	0	0	0	1	1	1
50	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2
51	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0
52	3	2	2	1	1	2	1	1	2	0	3	3	2	1	2
53	3	0	0	0	0	1	1	2	1	0	0	1	0	0	0
54	2	2	1	2	1	2	2	1	2	1	0	3	2	2	1
55	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
56	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0
57	3	2	2	3	2	3	3	2	2	2	3	3	2	3	2
58	2	2	3	1	2	2	3	2	1	0	2	1	0	0	0
59	2	1	2	0	0	1	0	0	0	0	0	0	0	0	0
60	2	2	3	2	3	3	3	2	3	3	4	4	3	2	2
61	2	1	2	0	1	3	2	2	1	0	0	1	1	1	1
62	4	3	4	1	3	2	2	3	2	2	2	2	1	1	1
63	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
64	2	0	2	1	0	2	1	1	3	3	1	1	1	1	0
65	2	1	1	0	1	0	1	2	1	0	1	1	0	0	1
66	2	1	3	1	2	1	1	0	0	0	1	2	0	1	1
67	3	3	3	2	1	3	2	2	1	1	2	2	3	2	1
68	3	2	4	1	1	2		1		1	1	4	1	0	1
69	4	4	4	0	0	0	0	0	0	0	0	2	0	1	0
70	2	0	0	0	1	2	0	0	0	0	1	2	0	0	0
71	3	1	3	2	2	3	3	2	2	1	2	3	2	0	0
72	2	2	2	0	1	2	1	2	1	0	1		1	1	0
73	2	2	2	2	2	1	1	2	1	0	0	1	1	1	0
74	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
75	4	2	2	2	1	2	1	1	0	1	1	1	1	1	1
76	4	2	0	1	4	3	3	0	3	3	4	4	0	0	0

APPENDIX G-II

Individual Pre-survey Responses – Semester 2

Student	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
77	2	1	3	0	0	1	0	1	0	0	1	2	0	0	0
78	4	3	4	2	3	3	2	2	3	1	2	3	2	1	1
79	2	3	3	1	2	0	0	1	0	0	1	1	1	0	0
80															
81	1	1	2	1	2	2	1	2	1	1	0	1	1	0	1
82	2	3	3	1	1	1	1	2	1	1	2	2	1	1	1
83	3	1	2	1	1	1	1	1	1	1	1	1	1	1	1
84	1	2	1	1	0	1	1	2	1	0	0	2	1	1	0
85	2	2	3	1	2	2	1	1	1	2	2	3	1	1	1
86															
87	3	3	3	2	3	3	1	1	2	0	1	3	2	0	1
88	1	0	2	0	0	1	0	0	0	1	0	1	0	0	1
89	1	1	2	1	0	2	0	1	0	0	1	1	0	1	0
90	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1
91	2	2	2	1	1	1	0	1	1	1	2	3	2	0	0
92	1	1	1	0	0	2	1	1	2	1	0	0	0	0	1
93	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
94	1	1	2	1	2	2	1	1	0	0	1	1	1	0	0
95	2	2	3	1	1	3	1	1	2	1	1	1	1	2	1
96	1	2	2	1	1	1	1	2	1	1	1	2	1	1	1
97	0	0	1	0	1	1	0	1	0	0	2	1	0	0	0
98	2	1	2	1	2	1	1	0	1	0	0	2	0	0	0
99	2	0	1	0	1	1	0	0	1	0	1	2	0	0	0
100	1	1	2	1	1	2	2	2	1	1	2	2	1	1	0
101	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2
102	1	0	1	2	2	2	1	2	0	0	1	2	0	0	0
103	2	1	1	1	0	1	0	1	0	0	1	1	0	0	0
104	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0
105	2	1	2	1	1	1	1	1	1	1	0	0	0	0	0
106	2	2	3	0	0	0	2	2	1	0	0	1	0	0	0
107	4	3	4	3	4	3	3	2	4	3	4	4	3	4	4
108	3	2	2	0	0	1	2	2	0	0	0	0	0	0	0
109	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0
110	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
112	2	3	2	1	2	1	2	2	0	0	1	1	2	2	1

113	2	1	0	0	0	1	1	1	1	1	3	1	0	0	0
114	2	0	2	0	1	1	1	0	0	0	0	0	0	1	0
115	0	1	1	1	2	2	2	1	1	1	2	2	1		1
116	2	0	3	0	0	0	0	0	0	0	0	1	0	0	0
117	2	2	2	2	2	1	0	0	0	0	1	1	0	1	1
118	1	2	2	1	1	1	2	0	1	0	2	2	2	1	0
119	2	1	2	0	1	1	2	2	1	0	1	1	0	1	0
120	1	0	2	0	0	1	1	0	0	0	2	3	1	0	0
121	2	1	1	0	0	0	0	0	0	0	0	2	0	0	0
122	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
123	2	1	2	2	2	2	2	2	2	1	2	2	2	2	2
124	2	1	2	2	2	2	1	1	2	2	1	2	1	2	1
125	2	2	3	1	1	3	1	1	0	0	2	2	0	0	0
126	3	3	2	0	0	1	0	1	0	0	0	2	0	0	0
127	2	2	0	0	1	1	1	2	2	0	2	3	0	0	0
128	2	2	1	2	1	3	2	2	2	1	1	1	1	1	2
129	0	0	2	0	0	2	1	3	0	0	0	1	0	0	1
130	2	1	2	0	0	1	0	1	1	2	1	1	1.5	1	1
131	1	2	1	0	1	2	1	2	0	0	0	1	1	0	1
132	0	1	2	0	0	2	1	1	0	0	1	3	0	1	0
133	2	1	3	0	1	1	1	1	0	0	0	0	0	0	0
134	0	0	0	0		0	0	0	1	1	1	2	0	0	0
135	4	3	3	0	1	1	1	2	2	0	0	2	2	3	0
136	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
137	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0
138	2	2	2	1	1	2	2	1	1	1	1	2	1	1	1
139	2	2	3	0	0	1	1	2	1	0	2	1	0	0	0
140	3	3	4	3	2	2	4	3	3	2	3	4	2	2	2
141	2	3	2	1	2	1	0	1	1	1	1	1	0	1	0
142	2	2	2	0	0	1	1	1	1	0	2	1	0	0	0
143	2	1	2	1	0	2	3	4	1	1	1	1	1	1	2
144	2	4	2	1	0	1	0	1	0	0	2	1	0	1	0
145	2	3	2	1	2	2	1	1	1	1	1	2	1	1	2
146	2	3	1	1	2	1	0	3	3	1	2	2	1	0	1
147	2	1	2	0	0	0	0	0	0	0	2	1	1	0	0
148	0	1	1	0	0	1	1	0	1	0	2	2	1	1	0
149	3	4	2	1	1	1	2	2	1	0	1	3	2	1	0
150	2	3	2	0	1	0	0	1	0	0	2		2	1	0
151	2	2	3	1	2	2	1	0	0	0	1	0	1	0	1
152	1	2	2	2	1	2	1	1	2	1	1	0	0	0	0

APPENDIX G-III

Totals for Pre-Survey Response – Semester 1															
	Survey Question														
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
MEAN =	2.1	1.6	2	0.9	1.1	1.4	1.1	1.1	0.9	0.6	1.1	1.6	0.8	0.7	0.6
MODE =	2	2	2	1	0	1	1	0	0	0	0	1	0	0	0
MEDIAN =	2	2	2	1	1	1	1	1	1	0	1	1	1	1	0
# of 0's =	2	8	4	28	26	12	23	30	34	47	29	17	35	36	40
# of 1's =	13	24	15	30	25	31	25	19	23	18	23	21	22	28	26
# of 2's =	38	32	35	13	17	21	20	18	13	7	17	19	15	10	10
# of 3's =	19	10	18	5	7	12	7	8	5	4	4	14	4	1	0
# of 4's =	4	1	4	0	1	0	0	1	0	0	3	4	0	1	0

Totals for Pre-Survey Response – Semester 2															
	Survey Question														
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
MEAN =	1.7	1.5	1.9	0.7	1.0	1.3	0.9	1.2	0.8	0.5	1.1	1.5	0.7	0.6	0.5
MODE =	2	1	2	0	0	1	1	1	0	0	1	1	0	0	0
MEDIAN =	2	1	2	1	1	1	1	1	1	0	1	1	1	0	0
# of 0's =	10	14	5	33	27	12	25	17	31	44	22	11	36	39	44
# of 1's =	16	25	18	30	26	36	33	33	29	24	29	30	25	26	23
# of 2's =	38	19	33	9	17	20	13	20	10	5	20	22	11	6	6
# of 3's =	7	14	15	2	2	5	2	3	3	1	2	8	1	1	0
# of 4's =	3	2	3	0	1	0	1	1	1	0	1	2	0	1	1

APPENDIX G-IV

Individual Post-survey Responses – Semester 1

	Survey Question														
Student	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**	**#15**
1	3	2	3	2	2	4	3	3	4	3	3	4	3	3	2
2	3	3	2	3	2	4	3	1	4	3	3	4	2	3	2
3	3	3	3	2	2	3	4	3	4	3	2	3	3	3	2
4	1	3	2	2	1	3	1	2	2	1	3	3	1	1	2
5	3	3	3	4	3	4	4	4	4	4	3	3	3	4	3
6	2	3	2	2	1	3	2	1	2	2	2	2	2	2	2
7	4	3	4	4	3	3	3	4	4	4	4	4	3	4	3
8	1	3	3	3	2	4	2	3	3	4	3	4	3	2	2
9	0	1	1	3	1	2	2	3	3	3	2	3	2	1	1
10	3	3	3	3	3	3	3	3	3	3	3	4	2	3	2
11	3	3	2	2	3	3	3	4	3	3	3	3	2	2	3
12	3	2	4	4	3	3	3	3	3	3	3	4	3	3	3
13	3	2	4	3	3	2	3	2	4	3	2	3	2	3	3
14	3	4	4	3	3	4	3	3	4	3	4	3	3	2	2
15	1	1	1	3	3	4	3	3	4	3	3	4	3	3	2
16	3	3	3	3	4	4	2	3	4	4	3	3	3	3	3
17	3	2	3	4	3	4	3	3	4	4	4	3	3	4	3
18	3	2	2	3	3	3	3	3	4	4	3	2	3	3	3
19	3	2	2	1	0	3	3	3	2	2	3	3	2	3	2
20	4	2	4	3	3	4	3	4	4	4	4	3	3	3	2
21	4	3	4	3	2	3	2	3	3	3	3	3	2	3	2
22	3	2	3	3	3	3	3	3	2	3	3	3	3	3	3
23	3	3	2	3	3	3	2	2	3	3	2	3	3	2	3
24	3	3	4	2	3	3	3	3	3	3	3	3	3	3	3
25	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3
26	3	1	4	4	2	3	2	4	3	3	2	4	4	3	1
27	3	3	3	3	2	3	3	3	4	4	3	3	4	4	3
28	3	2	3	2	3	2	3	2	3	4	3	3	2	2	3
29	3	3	3	2	2	2	2	2	2	3	3	2	2		
30	4	3	4	3	3	3	3	3	3	3	4	4	3	3	4
31	3	4	4	4	4	4	4	3	4	3	4	4	4	4	3
32	2	3	3	2	3	4	4	3	4	4	4	4	2	3	3
33	3	2	2	3	3	3	2	2	3	3	3	3	2	3	3
34	3	2	3	3	2	3	2	1	3	2	2	1	2	1	1
35	2	2	2	3	2	2	2	2	2	3	1	1	1	2	2

36	3	2	3	4	2	4	3	2	3	4	3	4	2	2	3
37	2	3	3	4	2	3	3	3	3	4	2	4	2	1	3
38	2	2	3	2	2	2	2	3	2	3	3	3	2	2	2
39	3	3	2	2	1	2	3	3	3	3	2	2	2	2	2
40	2	3	3	3	3	3	3	3	3	4	3	4	3	3	3
41	3	4	3	4	3	3	3	4	4	4	3	3	3	4	3
42	2	2	3	2	4	4	3	2	4	3	4	3	3	3	4
43	3	3	3	3	3	4	3	2	3	3	3	4	3	3	3
44	2	3	3	2	2	3	2	3	3	2	1	2	2	1	2
45	3	3	3	2	3	3	3	4	3	3	4	4	3	2	3
46	1	2	2	2	2	3	2	2	3	3	1	2	2	2	2
47	2	2	4	4	3	3	3	1	4	4	2	2	4	4	4
48	4	3	2	2	3	3	4	3	2	4	3	4	3	2	2
49	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3
50	3	3	3	3	3	3	3	3	3	4	3	4	3	3	3
51	2	2	2	3	2	2	3	2	3	3	3	3	3	3	2
52	3	4	4	3	2	3	4	3	4	4	3	4	3	3	3
53	4	3	3	4	3	3	4	4	4	4	3	3	2	2	2
54	4	3	3	3	3	4	3	4	4	4	4	4	3	3	3
55	3	2	2	4	2	3	3	3	4	4	3	3	3	3	3
56		2	2	3	2	3	2	2	3	2	3	3	2	3	3
57	3	2	3	2	2	2	2	3	2	2	2	2	2	3	2
58	2	2	3	2	0	2	3	2	3	4	2	3	1	1	0
59	2	2	3	4	3	4	3	2	3	4	2	3	3	3	2
60	4	3	4	3	3	3	3	3	4	4	3	3	3	3	3
61	3	2	3	4	4	4	2	4	4	4	2	4	3	4	2
62	4	2	4	4	3	4	3	4	3	3	4	3	3	3	4
63	1	2	2	3	3	3	2	3	3	4	4	2	2	2	2
64	3	3	4	3	3	4	3	3	4	4	4	3	3	3	3
65	4	3	3	3	2	3	4	4	3	4	3	2	3	4	2
66	4	3	4	2	3	3	2	4	4	3	3	3	2	3	2
67	4	4	3	3	3	3	3	3	3	4	3	3	3	3	3
68	3	3	3	3	3	4	4	3	3	4	2	4	3	4	2
69	4	3	4	4	4	4	4	3	4	3	4	4	4	4	4
70	2	2	2	4	2	2	2	2	2	2	1	1	1	1	1
71	3	2	4	2	4	4	4	2	4	2	1	4	3	4	1
72	3	3	4	3	3	4	4	4	4	4	4	4	4	3	3
73		3	3	3	2	4	3	2	4	1	3	4	3	3	2
74	3	2	3	2	1	3	2	3	4	3	2	3	2	2	1
75	3	2	3	3	3	3	2	3	3	3	3	3	2	2	2
76	4	2	3	3	3	3	3	2	4	4	4	4	3	3	3

APPENDIX G-V

Individual Post-survey Responses - Semester 2															
	Survey Question														
Student	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**	**#15**
77	3	3	3	4	2	3	3	4	3	4	3	4	2	4	3
78	3	3	3	4	4	3	4	4	4	4	3	3	3	4	3
79	3	4	3	3	2	3	2	3	4	4	3	4	2	2	3
80	2	2	3	4	3	4	3	1	3	4	3	4	3	3	3
81	3	2	2	3	3	3	2	3	3	3	3	2	2	3	2
82	3	4	3	4	3	4	3	3	4	4	3	3	3	3	3
83	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3
84	2	1	2	2	3	2	2	3	2	2	2	3.5	1	2	1
85	3	3	3	3	3	3	3	2	3	3	2	3	3	3	2
86	2	2	2	3	2	3	3	3	3	3	3	3	3	2	2
87	3	3	3	3	3	4	3	3	4	4	3	4	3	4	3
88	3	3	3	3	2	3	3	3	3	3	2	3	3	3	2
89	3	3	3	4	2	3	2	3	3	3	3	4	3	3	3
90	4	3	3	3	2	3	2	4	3	4	3	4	3	4	3
91	3	3	4	2	2	3	3	2	3	3	2	2	3	3	3
92	1	2	2	3	2	2		3	2	2	4	4	3	4	1
93	4	3	4	1	1	1	0	1	2	1	4	4	2	2	1
94	0	0	0	3	1	3	2	3	2	2	2	2	1	1	1
95															
96	2	3	2	3	2	4	2	4	3	4	2	3	2	3	2
97	3	2	3	3	2	3	3	3	3	3	2	2	2	2	2
98	2	2	3	3	3	2	2	3	3	3	2	3	2	3	2
99	3	3	4	3	3	4	3	4	3	4	2	2	3	4	2
100	2	3	3	3	2	4	3	4	4	3	3	4	3	3	3
101	3	3	3	3	2	2	2	3	3	3	2	2	2	2	2
102	0	0	2	4	2	3	4	4	4	4	2	4	2	4	2
103	3	3	3	2	3	3	3	3	4	3	2	3	3	4	3
104	2	2	4	3	3	3	2	3	3	3	2	3	2	3	2
105	3	3	2	2	3	3	3	3	3	3	2	2	3	3	2
106	2	3	4	4	3	3	2	4	4	2	2	2	3	3	2
107	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
108	3	3	2	3	2	2	2	3	3	2	3	2	2	2	2
109	2	3	3	4	2	3	3	4	2	2	2	2	3	4	2
110	3	1	2	2	2	3	2	3	3	3	3	3	2	2	2
111	3	2	2	2	2	2	2	2	3	3	2	2	3	2	2

112	2	2	3	4	3	3	3	2	4	4	3	2	3	3	2
113	3	3	3	3	3	3	3	3	4	4	2	3	3	3	3
114	3	2	3		3	3	3	3	3	4	3	2	2	2	2
115	2	3	3	2	2	1	2	3	3	3	3	3	2	2	2
116	3	0	2	3	0	2	3	4	4	4	1	1	1	0	0
117	2	3	2	3	1	1	2	2	3	4	3	2	1	2	1
118	0	0	2	3	2	2	1	2	3	3	1	2	1	1	1
119	2	2	3	2	2	3	3	3	3	3	2	2	3	3	2
120	2	2	2	3	2	3	3	4	3	3	3	3	2	2	2
121	3	2	2	3	1	2	1	2	3	3	1	2	1	2	0
122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
123	3	2	3	4	3	2	2	3	2	3	2	4	3	4	2
124	2	1	3	1	2	2	2	2	3	3	3	3	1	2	2
125	4	4	3	4	3	4	4	3	4	3	4	3	4	3	3
126	3	3	2	4	2	2	2	3	4	4	3	2	3	4	3
127	2	1	2	4	0	2	2	3	3	1	3	3	2	2	2
128	3	3	3	4	3	4	3	3	4	3	3	3	3	3	3
129	2	2	2	3	2	3	3	3	2	2	2	2	3	2	2
130	2	3	3	3	2	2	1	3	2	3	3	2	4	2	3
131	3	3	3	4	3	3	3	4	4	4	3	3	3	3	3
132	4	3	2	4	3	4	3	2	4	4	3	3	3	4	2
133	3	3	4	3	3	4	3	4	3	3	3	3	4	2	3
134	0	2	3	3	2	3	2	2.5	2.5	2	2	3	2	3	1
135	4	4	4	3	4	4	3	4	4	3	4	4	3	3	3
136	1	2	2	3	2	2	2	2	2	1	2	1	2	2	1
137	2	1	3	4	2	3	3	3	2	4	2	2	3	2	2
138	3	3	3	3	2	2	3	3	3	4	3	3	3	3	2
139		3	2	3	2	3	3	3	3	4	2	2	3	2	2
140	3	3	4	4	4	3	4	3	4	4	3	3	3	3	3
141	2	3	2	1	1	2	2	1	2	3	1	1	2	1	2
142	3	3	3	4	4	4	3	3		4	2	2	3	4	3
143	4	3	3	4	4	2	3	4	4	4	1	1	1	3	2
144	4	4	3	4	2	2	3	4	4	4	2	4	3	4	1
145	3	3	2	3	4	3	3	3	3	4	3	3	2	2	3
146															
147	2	2	3	3	3	3	2	3	3	3	2	3	3	2	2
148	3	2	3	3	3	2	3	3	3	3	3	3	2	3	2
149	3	4	3	4	4	4	3	4	4	4	4	4	4	4	4
150	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
151	3	3	3	2	1	1	3	3	3	3	4	3	2	4	2
152	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

APPENDIX G-VI

Totals for Post-survey Responses - Semester 1															
	Survey Question														
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
MEAN =	2.8	2.6	3.0	2.9	2.6	3.2	2.8	2.8	3.3	3.3	2.9	3.1	2.6	2.7	2.5
MODE =	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
MEDIAN =	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
# of 0's =	1	0	0	0	2	0	0	0	0	0	0	0	0	0	1
# of 1's =	5	3	2	1	5	0	1	4	0	2	5	3	4	7	6
# of 2's =	13	31	17	22	24	11	23	19	10	8	16	10	26	17	29
# of 3's =	41	37	38	36	39	41	40	39	34	34	39	36	40	39	34
# of 4's =	14	5	19	17	6	24	12	14	32	32	16	27	6	12	5

Totals for Post-survey Responses - Semester 2															
	Survey Question														
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
MEAN =	2.5	2.5	2.7	3	2.3	2.7	2.5	2.9	3.1	3.1	2.5	2.7	2.5	2.7	2.1
MODE =	3	3	3	3	2	3	3	3	3	3	3	3	3	3	2
MEDIAN =	3	3	3	3	2	3	3	3	3	3	3	3	3	3	2
# of 0's =	5	5	2	1	3	1	2	1	1	1	1	1	1	2	3
# of 1's =	2	5	0	3	7	4	3	3	0	3	5	4	8	3	9
# of 2's =	23	21	25	11	33	22	26	12	13	10	30	25	24	26	37
# of 3's =	36	37	39	36	24	34	38	40	37	33	32	29	37	27	24
# of 4's =	7	6	8	22	7	13	4	17	21	27	6	14	4	16	1

APPENDIX G-VII

Pre	Post	QUESTION	Number of Students With Response on the. Pretest	Posttest	Percentage of Students With Response on the. Pretest	Posttest
Pre- and Posttest Comparison - Semester 1						
(*76 Students in semester 1 group)						
#3	#34	Identify the parts of a wave				
		all parts correct	1	49	1.3%	64.5%
		crest/ trough	12	21	15.8%	27.6%
#1	#35	What is a wave?				
		mechanical/electromagnetic	0	18	0.0%	23.7%
		matter/space	0	7	0.0%	9.2%
		longitudinal/transverse	0	10	0.0%	13.2%
		parallel/perpendicular	0	1	0.0%	1.3%
		energy/disturbance/vibration	12	43	15.8%	56.6%
		moving/travels/transports	15	10	19.7%	13.2%
		rays/signal	2	0	2.6%	0.0%
		water	2	0	2.6%	0.0%
		polarizers	0	2	0.0%	2.6%
#4	#36	What affects the speed of a wave?				
		density	1	44	1.3%	57.9%
		matter/medium	5	23	6.6%	30.3%
		temperature	0	8	0.0%	10.5%
		force, energy, volume	9	7	11.8%	9.2%
		frequency, amplitude, wavelength	9	30	11.8%	39.5%
		distance	2	3	2.6%	3.9%
		source	1	1	1.3%	1.3%
		type	2	2	2.6%	2.6%

#5	#37	How do waves apply to life?				
		hear/see	30	51	39.5%	67.1%
		Water	0	11	0.0%	14.5%
		microwaves/cell phones	1	14	1.3%	18.4%
		Doppler	0	3	0.0%	3.9%
		radio/ tv	7	22	9.2%	28.9%
		Heat	1	2	1.3%	2.6%
		Seismic	1	1	1.3%	1.3%
		x-rays	0	3	0.0%	3.9%
		radar/sonar	1	2	1.3%	2.6%
#9	#38	Venn diagram on light/sound				
		see/hear	45	30	59.2%	39.5%
		transverse/longitudinal	0	25	0.0%	32.9%
		electromagnetic/mechanical	1	24	1.3%	31.6%
		perpendicular/parallel	0	1	0.0%	1.3%
		Polarized	0	4	0.0%	5.3%
		fastest in space/fastest in solids	7	31	9.2%	40.8%
		Refract	0	13	0.0%	17.1%
		Reflect	2	16	2.6%	21.1%
		Diffract	0	4	0.0%	5.3%
		Doppler	0	1	0.0%	1.3%
		Amplitude: brightness/volume	0	3	0.0%	3.9%
		frequency: color/pitch	2	7	2.6%	9.2%
		Waves	30	47	39.5%	61.8%
		Energy	4	2	5.3%	2.6%

APPENDIX G-VIII

Pre- and Posttest Comparison - Semester 2						
(*76 Students in semester 2 group)						
			Number of Students With Response on the.		**Percentage of Students With Response on the.**	
Pre	**Post**	**QUESTION**	**Pretest**	**Posttest**	**Pretest**	**Posttest**
#3	#34	Identify the parts of a wave				
		all parts correct	0	53	0.0%	69.7%
		crest/ trough	6	22	7.9%	28.9%
#1	#35	What is a wave?				
		mechanical/electromagnetic	0	25	0.0%	32.9%
		matter/space	0	27	0.0%	35.5%
		longitudinal/transverse	0	13	0.0%	17.1%
		parallel/perpendicular	0	6	0.0%	7.9%
		energy/disturbance/vibration	6	66	7.9%	86.8%
		moving/travels/transports	34	53	44.7%	69.7%
		rays/signal	1	0	1.3%	0.0%
		water	0	0	0.0%	0.0%
		polarizers	0	0	0.0%	0.0%
#4	#36	What affects the speed of a wave?				
		density	3	39	3.9%	51.3%
		matter/medium	6	39	7.9%	51.3%
		temperature	8	39	10.5%	51.3%
		force, energy, volume	11	3	14.5%	3.9%
		frequency, amplitude, wavelength	5	18	6.6%	23.7%
		distance	1	1	1.3%	1.3%
		source	2	0	2.6%	0.0%
		type	3	1	3.9%	1.3%

#5	#37	How do waves apply to life?				
		hear/see	15	39	19.7%	51.3%
		water	6	6	7.9%	7.9%
		microwaves/cell phones	4	26	5.3%	34.2%
		Doppler	0	1	0.0%	1.3%
		radio/ tv	12	34	15.8%	44.7%
		heat	2	4	2.6%	5.3%
		seismic	1	2	1.3%	2.6%
		x-rays	0	8	0.0%	10.5%
		radar/sonar/ultrasound	0	7	0.0%	9.2%
#9	#38	Venn diagram on light/sound				
		see/hear	27	21	35.5%	27.6%
		transverse/longitudinal	0	47	0.0%	61.8%
		electromagnetic/mechanical	0	51	0.0%	67.1%
		perpendicular/parallel	0	4	0.0%	5.3%
		polarized	0	4	0.0%	5.3%
		fastest in space/fastest in solids	7	24	9.2%	31.6%
		refract	0	9	0.0%	11.8%
		reflect	0	16	0.0%	21.1%
		diffract	0	9	0.0%	11.8%
		Doppler	0	1	0.0%	1.3%
		Amplitude: brightness/volume	3	2	3.9%	2.6%
		frequency: color/pitch	0	3	0.0%	3.9%
		waves	35	49	46.1%	64.5%
		energy	1	16	1.3%	21.1%

APPENDIX G-IX

Posttest Comparison - Semester 1 and Semester 2						
(*76 Students in each group)						
Pre	**Post**	**QUESTION**	**Semester 1**		**Semester 2**	
#3	#34	Identify the parts of a wave				
		all parts correct	49	64.5%	53	69.7%
		crest/ trough	21	27.6%	22	28.9%
#1	#35	What is a wave?				
		mechanical/electromagnetic	18	23.7%	25	32.9%
		matter/space	7	9.2%	27	35.5%
		longitudinal/transverse	10	13.2%	13	17.1%
		parallel/perpendicular	1	1.3%	6	7.9%
		energy/disturbance/vibration	43	56.6%	66	86.8%
		moving/travels/transports	10	13.2%	53	69.7%
		rays/signal	0	0.0%	0	0.0%
		water	0	0.0%	0	0.0%
		polarizers	2	2.6%	0	0.0%
#4	#36	What affects the speed of a wave?				
		density	44	57.9%	39	51.3%
		matter/medium	23	30.3%	39	51.3%
		temperature	8	10.5%	39	51.3%
		force, energy, volume	7	9.2%	3	3.9%
		frequency, amplitude, wavelength	30	39.5%	18	23.7%
		distance	3	3.9%	1	1.3%
		source	1	1.3%	0	0.0%
		type	2	2.6%	1	1.3%

#5	#37	How do waves apply to life?				
		hear/see	51	67.1%	39	51.3%
		water	11	14.5%	6	7.9%
		microwaves/cell phones	14	18.4%	26	34.2%
		Doppler	3	3.9%	1	1.3%
		radio/ tv	22	28.9%	34	44.7%
		heat	2	2.6%	4	5.3%
		seismic	1	1.3%	2	2.6%
		x-rays	3	3.9%	8	10.5%
		radar/sonar	2	2.6%	7	9.2%
#9	#38	Venn diagram on light/sound				
		see/hear	30	39.5%	21	27.6%
		transverse/longitudinal	25	32.9%	47	61.8%
		electromagnetic/mechanical	24	31.6%	51	67.1%
		perpendicular/parallel	1	1.3%	4	5.3%
		polarized	4	5.3%	4	5.3%
		fastest in space/fastest in solids	31	40.8%	24	31.6%
		refract	13	17.1%	9	11.8%
		reflect	16	21.1%	16	21.1%
		diffract	4	5.3%	9	11.8%
		Doppler	1	1.3%	1	1.3%
		Amplitude: brightness/volume	3	3.9%	2	2.6%
		frequency: color/pitch	7	9.2%	3	3.9%
		waves	47	61.8%	49	64.5%
		energy	2	2.6%	16	21.1%

APPENDIX H-I

PRETEST

#3: What are the parts of a wave?

Student A:
Crest, trough

Student B:
Dunno

Student C:
I have no idea.

Student D:
Don't know

Student E:
?

Student F:
I dunno!

POSTTEST

#34: Identify the parts of the wave.

Student A:
All parts correct.

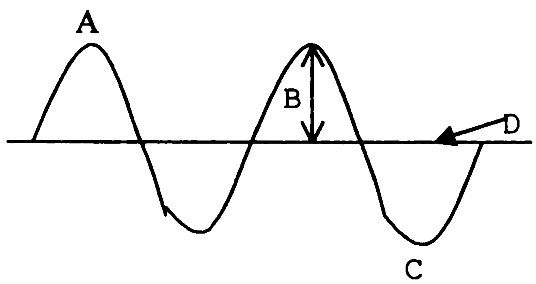
Student B:
A, B, and C correct.

Student C:
B and C correct

Student D:
All parts correct

Student E:
A, B, and C correct.

Student F:
A and C correct.



A = crest
B = amplitude
C = trough
D = equilibrium

APPENDIX H-II

PRETEST	POSTTEST
#1: What is a wave?	**#35: What is a wave? (What determines how and where a wave can travel?)**
<u>Student A:</u> 	<u>Student A:</u> A wave carries energy from one place to another. The kind and amount of energy it transfers constitutes how and where it travels.
<u>Student B:</u> Not sure	<u>Student B:</u> A wave is particles of a medium vibrating.
<u>Student C:</u> I have no idea.	<u>Student C:</u> A wave is a vibration from an object. The frequency, the amplitude and the wavelength determines how and where a wave can travel. All of those that I have mentioned make up how loud how fast and how long you hear the sound.
<u>Student D:</u> Don't know.	<u>Student D:</u> A wave transfers energy through a medium. The 2 ways of how waves travel are longitudinal and transverse. A longitudinal wave travels parallel to the motion of the wave. Transverse waves travel perpendicular to the motion of the wave. The two ways we categorize where a wave can travel is electromagnetic and mechanical waves. Mechanical waves can only travel through matter, but electromagnetic can travel through matter and space.
<u>Student E:</u> ?	<u>Student E:</u> A wave is energy going from one place to another. The things that determine where the wave goes depends on weather and density.
<u>Student F:</u> A wave carries a stream of something.	<u>Student F:</u> A wave can be many things. It can be sound, or light, transverse or mechanical. Some waves we can see such as a water wave and some we can't like a sound wave.

APPENDIX H-III

PRETEST	POSTTEST
#4: What affects the speed of a wave?	**#36: What affects the speed of a wave?**
Student A: Wind	Student A: The speed of the wave is affected by the frequency. Frequency is how many times a wave travels past a certain point each second, so if the frequency is higher, the wave is going faster.
Student B: Don't know	Student B: The density affects the speed of a wave. The medium in which the wave is traveling also affect the speed of a wave.
Student C: Solid objects	Student C: The speed of a wave is affected by the substance a wave is in, for example in water a wave can move faster because it is more dense and the denser it is its easier for a wave to move in.
Student D: Don't know	Student D: According to the Kinetic Theory, temperature is one way that effects the speed of a wave, because when it is hotter the particles are more spread and vice versa. Density is another thing that affects the speed of a wave. With light waves, the more dense a medium is the slower it goes. With sound waves, the more dense a medium is the faster the wave is.
Student E: The air around the wave, and speed	Student E: Things that affects speed of a wave are weather. If its warm it will go the fastest. If its cold it won't go as fast.
Student F: I dunno!	Student F: How close or far apart the waves per second are and how many vibrations.

APPENDIX H-IV

PRETEST	POSTTEST
#5: How do waves apply to life?	**#37: How do waves apply to life? (What are some applications of waves in everyday life? – Be specific and explain.)**
Student A: Helps you see, hear	Student A: To see and hear we need waves. What we see relys on light waves reflecting off something and coming back to your eye. To hear, your ear picks up sound waves from around you.
Student B: unknown	Student B: Waves are around us and are used all the time. Every time we speak we produce sound waves. When you break a bone you get x-rays taken.
Student C: I have no idea	Student C: Waves apply to life everyday by hearing any kind of sound. For example the radio when you are on your way to work. There are also light waves that you see every day like in a classroom or at your office even when you go outside in the middle of the day when it's sunny out.
Student D: Radio waves are the things we use that bounce off satellites in space and bring us television and radio. Light waves give a source of energy and heat to use. Air waves can affect the flight of a plane in the sky.	Student D: We use waves in many normal day things. For example, we use waves in sonar to find things under water. Sonar is when sound waves are shot down into the ocean and when it hits an object it bounces back up. We use light waves to do an x-ray on someone. We use radiowaves to get our favorite radio station. We use microwaves to heat our food. In order to break up a kidney stone, we use waves.
Student E: talking	Student E: For example a radio. We use that everyday. It receives waves and puts out sound waves so we can hear the music or news.
Student F: It helps carry sounds, colors So we can live.	Student F: Without waves in everyday life we would not see any color. All of the color we see is through waves. Waves makeup practically everything. Its how we hear and see what we do.

APPENDIX H-V

Venn Diagram on Light and Sound

RESPONSE	Students with response on the PRETEST (#9)	Students with response on the POSTTEST (#38)
See and hear	A C D	E
Transverse and longitudinal		D
Electromagnetic and mechanical		A D
Perpendicular and parallel		
Polarized		D
Fastest in space and fastest in solids	E	C D E
Amplitude: brightness and volume		D
Frequency: color and pitch		
Reflect		A D
Refract		A D
Diffract		A D
Doppler Effect		
Waves	A	A C D E F
Energy		D

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