Pre-service teacher understanding of propagation and resonance in sound phenomena

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This paper describes results of an ongoing investigation into the understanding of sound, mainly among preservice K-12 teachers. Recent work has focused on identifying difficulties in understanding sound propagation and resonance phenomena. We have found that within this population the concept of propagation, especially from one solid object to another, is not well understood.

I. INTRODUCTION

Sound is a topic that is typically taught in elementary grades, and appears in several states' benchmarks or standards for teaching science [1]. Some research has been done on children's conceptions of sound [2], and on college student conceptions and difficulties in sound in an introductory course [3-6]. However, there has been no research conducted on the understanding that teachers have in this topic. Thus it is natural to investigate the extent to which practicing and future K-12 teachers understand this topic. We are investigating the difficulties that these populations exhibit with the goal of developing a guided-inquiry-based *Sound* unit for teacher preparation and professional development. In this paper we will describe some difficulties that K-12 teachers have with specific concepts within sound.

The main population that is described in this study is a group of preservice elementary teachers in a *Physics by Inquiry (PbI)*[7] course at Grand Valley State University (GVSU), a regional, comprehensive institution in Allendale, MI.

The basic concepts that are being explored here involve the propagation of sound and the phenomenon of resonance. We are especially interested in how teachers/students appreciate the frequency of a sound as it propagates (neglecting a Doppler effect situation).

Previous work with these and similar populations has shown that teachers, in general, are able to distinguish between characteristics related to pitch and those related to volume. In Section 1 of *Sound*, teachers are led to recognize that sound is caused by vibrating objects, and that the frequency of the vibrations are related to the pitch of the sound produced. There is evidence that difficulties connecting frequency to pitch are addressed effectively in this section [8]. Later sections deal with propagation and resonance.

Most of the previous research in this area focuses on students' understanding of the wave model – and therefore wave properties – of sound. This is reasonable considering that sound is typically taught as an early example of a mechanical wave. However, when teaching elementary teachers our instructional approach is more phenomenological. Sound is introduced to the teachers in Section 1 of *Sound* not as waves, but rather as vibrations. After several sections dealing with sound and models of sound propagation and resonance, the teachers work through a curriculum on waves to expand their understanding in this new context.

For simplicity, the preservice teachers will be referred to as "students" and in-service teachers will be referred to as "teachers."

II. DATA

Once students explore how sound is generated and some of the characteristics of the sounds and the vibrations, they are asked a series of questions in Pretest 2 about propagation of sound from one object to another.

The context for these questions involves tuning forks and a meter stick. We use tuning forks because they produce a pure tone (*i.e.,* one with a single frequency), eliminating any effects that might occur using complex sounds that contain multiple frequencies.

A. Tuning fork – meter stick question

In part A of pretest 2, shown in Figure 1, students are asked whether a sound will be heard at the end of a meter stick in contact with a ringing tuning fork. Almost all – 14 out of 16 – students correctly responded that a sound would be heard. The remaining 2 students implied that the sound would not be audible but the meter stick would still be vibrating. Subsequently, students were asked about the pitch of the sound propagated through the stick. Only 7 out of 16 students recognized that the pitch of the sound in the meter stick is the same as that of the tuning fork (f_A). Another 7 out of 16 stated that the pitch heard at the end of the stick would be lower than f_A.

Two students are experimenting with tuning forks. Student 1 strikes fork A. When Student 2 stands approximately one meter away from Student 1 she *cannot* hear the tuning fork because it is too far away.

A. Student 1 then strikes fork A and then places the base of the fork on one end of a meter stick while the fork is still ringing. Student 2 is at the opposite end of the meter stick.

Will student 2 hear a sound when she places her ear near the end of the meter stick?

- If not, why not? Explain your reasoning.
- If so, compare the pitch of the sound heard by student 2 to that of the sound generated by the fork. Be as specific as you can. Explain your reasoning.

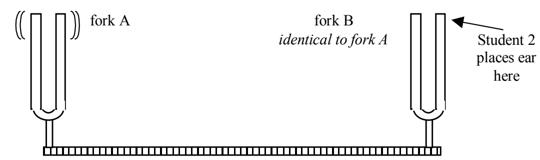
Figure 1: Part A

B. Identical tuning forks & meter stick question

Part B of pretest 2 (Figure 2) helps determine the consistency of the students reasoning. Students are asked if a sound will be heard from a second, identical tuning fork (fork B) placed at the opposite end of the meter stick from the ringing tuning fork (fork A). Fifteen of the 16 students correctly responded that a sound would be heard from fork B. It is interesting to note that the remaining student said that the meter stick *would* make a sound in part A, and that it would be the same pitch as the tuning fork.

The second part of this question asked students to characterize the pitch of the sound from fork B relative to the pitch of fork A. This question has a fairly high success rate: eleven of 16 correctly say that the pitch will be the same. Four of 16 students responded that the pitch heard from fork B is different from f_A; again, all 4 said the pitch would be lower.

B. Student 2 then takes fork B, *which is identical to fork A,* and places its base on the far end of the meter stick. Student 1 strikes fork A, and then places the base on the opposite end of the meter stick while fork A is still ringing.



Will student 2 hear a sound when she places her ear near fork B?

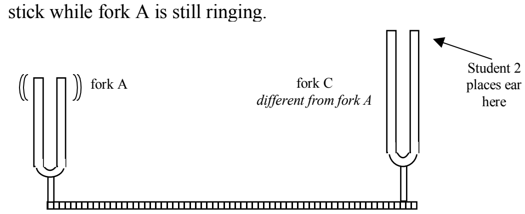
- If not, why not? Explain.
- If so, compare the pitch of the sound to that of the sound generated by fork A. Be as specific as you can. Explain.

Figure 2: Part B

C. Different tuning forks & meter stick question

In the third part of this pretest, shown in Figure 3, the second tuning fork, fork C is different from fork A. Thirteen of the 16 correctly stated that fork C would ring in this case. However, on the second part of the question, asking about the frequency of the sound, none of the students in this class came up with the correct answer. All responses indicated a lower pitched sound coming from fork C.

C. Student 2 then takes fork C, *which is different from forks A and B,* and places its base on the far end of the meter stick. Student 1 strikes fork A, and then places the base on the opposite end of the meter stick while fork A is still ringing.



Will student 2 hear a sound when she places her ear near fork C?

- If not, why not? Explain.
- If so, compare the pitch of the sound to that of the sounds generated by fork A and fork C when they are each struck. Be as specific as you can. Explain.

Figure 3: Part C

In the curriculum, students perform the experiments described in the pretest. After conducting the experiments, all students agree that all sounds heard have the same pitch.

III. DISCUSSION

The explanations that students gave to justify their responses – both correct and incorrect – fall into three basic categories. Two of these categories are somewhat predictable based on their observations and experimental results from Section 1 of *Sound*. The third category, however, is unexpected. These categories are discussed below.

A. Connecting sounds and vibrations

We discussed earlier how in Section 1 of *Sound* the students fairly successfully connect the properties of sounds (pitch and volume) to the properties of vibrations (frequency and amplitude). This linking leads not to one, but two possible outcomes. The first outcome is the desired one, namely that the students apply an understanding of the properties of vibrations to the sound phenomena they observe, such as propagation and resonance. In this outcome, students would say that the pitch of the sound heard from the meter stick would be the same as that of the tuning fork because the vibrating fork causes the meter stick to vibrate at the same rate. The second, less desirable outcome, is that the students apply their misconceptions about sound to the properties of vibrations. In this case, students would refer to the alteration of the vibrations when changing the medium or material that the sound is passing through.

The reasoning given for the correct responses in part A have a fairly wide range of detail and accuracy, as shown by the following responses:

- "…a fork makes a certain pitch and it's specific to that fork… The volume will be different, but not the pitch."
- "…the fork vibrations made the meter stick vibrate."
- "…the fork will vibrate the meter stick at the same frequency."

While many of the students who gave the correct response to part A invoked vibrations in their answer, some of the incorrect responses contained references to vibrations as well. One student said that the sound would be lower because "the vibrations will be traveling through the wooden meter stick." Another student was clearly undecided about a line of reasoning, stating that "sounds appear lower further away" and then "I also assume this has something to do with transmission of vibrations through other media…" These student excerpts suggest that both pedagogical outcomes of Section 1 described above have occurred in this population.

B. Size dependence of pitch

In Part A, there were 2 students who responded that the pitch of the sound would change going from the tuning fork to the meter stick because the distance traveled by the sound affects the pitch. Both students said the pitch would be lower. Difficulties with this idea could stem from two places. First, students could exhibit confusion between frequency and amplitude (or pitch and volume). Students who are confused about this distinction would explain the attenuation of the sound as a change in frequency or pitch. The second origin of this response could stem from experiments completed in the previous section in which students correlate object size with the pitch of the sound produced by that object.

In part C, nearly all of the explanations, whether they said the pitch changed or if there was no sound at all, attributed their response to the fact that fork C was larger or longer than fork A. Some students explicitly said the frequency would be the same as fork C, while others merely said it would be lower than f_A. Many students stated that fork C has to vibrate at its own natural frequency. These students appear to attribute the idea of resonance to a question asking about propagation.

C. Material dependence of pitch

In Part A of the pretest, a common error in reasoning was given by five of the 16 students. These students specifically mention the change in material as being responsible for the change in pitch. One student in particular remarked that the sound "would be lower because the medium it is traveling through would alter [the pitch]." Although students do not use the term (most of these students have not had any previous physics courses), this argument seems to incorporate ideas analogous to the refraction of light. Like light that appears to bend the image of a pencil between air and water, *something* disturbs or distorts the sound when it passes into the wood. Students think that the pitch of the sound is altered, even though frequency is unchanged upon refraction.

Of the five students who stated that the pitch is dependent on the material in part A, four were consistent in part B with this reasoning. Three of those students stated that the pitch became lower through the meter stick and then returned to its original value when passing back into the second metal tuning fork. One student, who said in part A that the pitch lowers "because the sound waves slow down as it travels through the meter stick," states in part B that "the waves speed up again between the prongs" to bring it back to the same pitch as fork A. The remaining student in this category seemed to think that passing through the wood permanently lowered the pitch.

It is noteworthy that the students who provided material-dependent-pitch reasoning in parts A and B did not do so in part C. Apparently, the idea that a larger fork makes a lower-pitched sound supercedes any other ideas related to propagation.

IV. ADDITIONAL RESULTS

Some of the above pretest questions have been asked of different populations of students and teachers. However, the GVSU class, whose results are discussed here, is the only group that was asked these questions in a single pretest. In order to frame some of the results described above, we will compare some of these results to those from other groups.

Part A, the tuning fork – meter stick question, has been given as a pretest question to two other classes. Three of these additional 35 students provide incorrect answers (that the pitch heard from the meter stick is lower) that explicitly mention the material dependence of the pitch.

Furthermore, Part C has been given to other groups of students and teachers as a stand-alone question. None of the 53 other respondents made any reference to the material dependence of the pitch.

V. CONCLUSIONS

We have reported a new model that students seem to have about the propagation of sound from one medium to another, namely that the pitch of a sound is dependent on the material through which the sound is passing.

Previous research on sound propagation in air [5,6] has not demonstrated this result, indicating that the solid-solid system is necessary to elicit this model.

Finally, this model is not elicited in situations that elicit simpler justifications such as the dependence of the pitch on the size of the object transmitting or propagating the sound.

The difficulties described here suggest several possibilities for future work. The pretest will be modified to differentiate between material- and size-dependent reasoning, and to explore possible pitch-volume confusion in this context. We will conduct interviews that will contain situations from both versions of the pretest to check student response variation, consistency, and depth.

As mentioned earlier, the *Sound* unit is in the process of development. We will administer and analyze post-test questions to assess the effectiveness of the unit.

VI. ACKNOWLEDGEMENTS

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