The Teaching Experiment – What it is and what it isn't

Paula V. Engelhardt, Edgar G. Corpuz, Darryl J. Ozimek, and N. Sanjay Rebello
Physics Department, Kansas State University, Manhattan KS, 66506-2601

Abstract: Much of the research to investigate how students' reason or what knowledge structures they possess and utilize have typically been done using the clinical interview format. The clinical interviews are often semi-structured and may or may not involve demonstration equipment. In the early 1980's, mathematics researchers began experimenting with a new style of interviewing which they termed the "teaching experiment." These two methods will be compared and contrasted within the context of sound. Students from a conceptually-based introductory physics course were interviewed using both formats in an effort to understand how they view the production of sound from musical instruments.

Introduction

David Ausubel comments "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly."[1] Typically, ascertaining what a student already knows has been done using the clinical interviewing style developed by Piaget.[2, 3] A technique known as the "teaching experiment" utilized by mathematics education researcher Steffe [4] may shed more light on how students' concepts change and are influenced by various instructional methods. This paper will examine the differences between the clinical interview and the "teaching experiment" by examining the types of information that one can glean by using these two methods within the context of sound.

Clinical Interviews

Clinical interviews have become the bread and butter method for determining what students understand of various physics phenomena. The method has been used at all levels of instruction from primary school to university graduate level. Typically, the format of the interview is semi-structured, having some pre-planning of the content, tasks, and questions.[5] The results of the interviews are then transferred to the learning environment, providing the instructor with a better understanding of how their students view particular concepts and what alternative explanations students may be expected to give. The goal of the interview is to understand students' current reasoning patterns *without* attempting to change them.

Teaching Experiment

The teaching experiment is a variation on the interview technique. It incorporates three components: modeling, teaching episodes, and individual or group interviews. The most important aspect of the teaching experiment is the modeling of the students' responses into a coherent picture of the students' progress over an extended period.[6]

Teaching episodes involve the teacher/interviewer, an observer, and the students under investigation. As with clinical interviews, the teaching episodes are recorded and analyzed. The analysis is then used to guide the next teaching episode. It is during this phase that the researcher's hypotheses are tested or perhaps abandoned based on responses given by the students. During the teaching episode, the students' reasoning is the focus of attention just as in the clinical interview.[6] The purpose of the observer in the teaching experiments is to help the teacher/interviewer understand the student and to aid in determining the next phase of the teaching episode. The observer offers a more objective view of the interactions that occur during a teaching episode.

These three components are not self-standing but are intimately interwoven. One does not carry out modeling of student responses without first having conducted an interview that might have included a teaching episode. Steffe and Thompson remark

> In their attempts to learn students' mathematics, the researchers create situations and ways of interacting with students that encourage the students to modify their current thinking.[6]

This aspect of the teaching experiment sets it apart from the clinical interview in that it is an acceptable outcome of the teaching experiment for students to modify their thinking.

Much of the work using the teaching experiment methodology has been in the field of mathematics. Two groups have adopted this methodology in their investigations of electricity concepts [7] and non-linear systems.[8]

Advantages of the teaching experiment

In terms of curriculum development and the evaluation of new teaching methods, the teaching experiment offers several advantages over the traditional clinical interview. First, the teaching episodes allow the testing of new techniques. Analysis can pinpoint which technique provided the students with the most conceptual growth. Second, it more closely mimics the natural classroom environment when performed with groups of students. Additionally, from a research perspective, it provides a training ground for graduate students in interview techniques. When the graduate student acts as an observer, they learn proper interview etiquette as well as the process of transcribing and analyzing transcripts.

The teaching experiment, learning cycle and Socratic teaching

The teaching experiment embraces both the learning cycle [9] and Socratic teaching [10] in its tenets. The structure of the interview resembles a Socratic dialog. Students are repeatedly asked probing questions to try and elicit as much of their reasoning and thought processes as possible. The questions tend to be focused around the activities or tasks that the students are asked to think about and explain.

The teaching experiment is also related to the learning cycle. A typical learning cycle consists of three stages, an exploration phase, concept introduction phase and concept application phase. In the exploration phase, students explore the concept under investigation through hands-on activities. In the concept introduction phase, an explanation of the observations that were performed in the exploratory phase is given a name and further refined. In the concept application phase, students apply the concept that they explored and later named to new situations. In the teaching experiment, there is a cycle associated with the students and another associated with the interviewer/researcher. The connections between these two cycles are depicted in Figure 1.

Our adaptation of the teaching experiment

At present, we are using the teaching experiment methodology with a group of conceptually- based introductory physics students to investigate how they understand the production of sound in musical instruments. The focus of the investigation is on their understanding of the relationship between the variables that affect the pitch of the sound that is produced. For example, variables of key interest in the cello are the thickness of the strings, the type of metal from which the string is made, the tension in the string, and the length of the string.

We have run two trials of the teaching experiment. In both trials, students are involved for one hour for three days. In the first trial, students met with us every other day over the course of one week. The first trial occurred prior to instruction on sound. In the second trial, students met with us once a week for three weeks. The greater time lag in the second trial allowed for time to distill the information gathered and to transcribe the previous teaching episode. The second trial occurred after brief instruction on sound.

Throughout the teaching experiment, multiple learning cycles occurred. Day 1, illustrated in Figure 1, covered a complete learning cycle related to the properties of waves. A second cycle explored the properties of standing and traveling waves. This cycle continued on Day 2 with further explorations of standing waves in demonstrations involving organ pipes, singing rods, and bugle (corrugated) tubes. Portions of the second cycle served as an exploration of relevant concepts for later application to musical instruments.

Teaching Experiment	Learning Cycle Phase	Student's perspective	Teacher/Interviewer's perspective
Teaching episode 1	Exploration	Explore the concept of waves through demonstrations such as wave machine, slinky, and stadium waves	Explores initial student's conception of wave and tests which demonstrations aid the students most in developing an understanding of waves
	Concept introduction	Introduction of transverse and longitudinal waves and elaboration on the properties of each	Clarifies student's initial and current conception of waves and verifies which demonstrations helped most in developing an understanding of a wave
	Concept application	Applies new knowledge to determine which type of wave sound is based on demonstrations using tin can telephones, speaker and feather, and sympathetic resonance of tuning forks	Evaluate demonstrations for their effectiveness in aiding students to build an understanding of the fact that sound is a longitudinal wave

Figure 1: Comparison of the learning cycle from the teacher/interviewer's perspective and the student's perspective to a teaching experiment covering sound in musical instruments

Demonstrations used in this third cycle included wine glasses, glass bottles (blowing over), organ pipes, singing pipes, sonometer, and Chladni plates. Day 3 finished cycles 2 and 3 with applications to musical instruments. The concepts introduced at the beginning of Day 3 served as the concept introduction phase for both cycles 2 and 3 and their application to musical instruments serving as the application phase.

During a particular teaching episode, the teacher/interviewer asked students to predict, observe, and explain what they saw or expected to happen in each demonstration. Students were allowed on their own to further explore demonstrations. The flow of the interview was always dictated by students' answers to questions posed by the teacher/interviewer. Additional demonstrations were created on the spot to help students answer questions that they posed during the course of explaining what they believed to be happening in a particular demonstration. At the end of each teaching episode, students were asked to reflect on the days' activities and draw connections between the activities, indicate where they still had questions, and make any other comments they thought were relevant. This is an adaptation of a recommendation by Komorek and Duit [8] to use questionnaires between teaching episodes to further aid the preparation of the next episode.

Results from Clinical interviews

Five clinical interviews were conducted with students taking a conceptually- based introductory physics course in spring 2003. These students had no prior instruction on sound. All had previously played a musical instrument. The focus of the interview was on the relationship between the variables (string length, tension, etc.) and how that affected the pitch of the sound that was produced.

Although detailed analysis of these interviews has not yet been completed, some general comments can be made. This group of students relied heavily on their personal experience having played a musical instrument. They tended to describe the sound produced by each musical instrument in terms of a vibration. The location of the vibration depended on the instrument being discussed. They could often correctly predict the pitch of the sound produced by the instrument. They related the length to the pitch – short length, low pitch, long length, high pitch, but were not often able to explain their reasoning in more detail.

Results from trial 1 of teaching experiment

One group of three students enrolled in a conceptually- based introductory physics course in summer 2003 volunteered to participate in the teaching experiment. All had previously played a musical instrument and participated prior to instruction on sound. The analysis is only partially completed. Here are a few general comments. These students relied more heavily on the demonstrations that were performed during the teaching episodes rather than their personal experience from playing musical instruments. They used the earlier demonstrations to strengthen their explanations.

Conclusions

Clinical interviews provided details of how students *currently* understand a particular physics concept. They reveal areas where students are confused, but cannot always reveal how best to create a change in students' thinking as this would violate the rule that one should not teach during an interview.[5] Through a teaching experiment one can discover which technique will produce a change and can follow that change. For example, the speaker with either a candle or feather placed in front of it appears to help students conclude that sound is a longitudinal wave. Students also need to have a firm grasp of the properties of longitudinal waves in order to make this connection. They especially need to understand that a longitudinal wave has its displacement and movement of the wave in the same direction.

Although clinical interviews provide a wealth of information about a students' current thinking of a particular topic, the teaching experiment can provide more robust information on how one can facilitate a shift in students' conceptions toward the scientific view. The information gathered can be used to aid instructors in selecting appropriate materials and help them determine the proper sequencing of activities. Teaching experiments mimic more closely the actual classroom environment.

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