A framework for student reasoning in an interview

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Abstract: We propose a framework to characterize students' reasoning in an interview. The framework is based on interview data collected by five researchers with different research goals. The participants were enrolled in various introductory physics courses at Kansas State University (KSU). Our framework includes *external inputs* (e.g. questions asked, verbal, graphic and other cues) from the interviewer and interview environment; *tools* (e.g. memorized or familiar formulae, laws and definitions, prior experiences) that the student brings to the interview; a *workbench* encompassing mental processes (e.g. induction, accommodation) that incorporate the inputs and tools; and the a*nswer* given by the student. We describe how the framework can be used to analyze interview data.

Introduction

Interviews have long been used in physics education research (PER). At least two issues influence the interpretation of interview data. First is the researcher's agenda. Second is the assumption that knowledge remains static while it is probed in an interview. This assumption overlooks situations in which students make up answers as they speak, especially when asked questions they may never have previously considered. Therefore, we need to be cognizant of the factors that may influence students' responses.

This paper addresses the following questions:

- How do students construct their reasoning during an interview?
- What factors mediate students' sense-making processes during an interview?

In light of these questions, we carefully examined a vast data set, which led to the emergence of a theoretical framework.

Relevant Literature

The above questions pertain to interviews that investigate student knowledge. Therefore, we are concerned with the interview as well as the object of its investigation – knowledge and reasoning.

Researchers have different ways of describing student knowledge. Driver, [1] Glaserfeld, [2] Redish [3] and others describe knowledge in terms of mental models that minimize the mental energy. Learners test these models in light of new experiences to modify or reorganize the models. These models can be nebulous complex structures incorporating incomplete, overlapping and even contradictory ideas. They may involve multiple representations, myriad rules and procedures or schemas that the student may not even be aware of. diSessa [4] believes in knowledge in pieces or "p-prims." Minstrell [5] has divided concepts into units called "facets." Hammer [6] describes "resources" as the smallest usable pieces of knowledge. Our framework is not anchored at any particular grain size, rather we consider all grain sizes equivalently.

Our framework pertains to the dynamics of reasoning and knowledge change in an interview. Piaget [7] describes this change in terms of assimilation (adapting our experiences to fit our knowledge) and accommodation (modifying our knowledge to account for our experiences). More recently researchers have talked about conceptual change in terms of conceptual combination [8] or hybridization [9].

Physics education researchers typically use a flexible semi-structured format that allows for follow-up questions. This flexibility makes the semi-structured format susceptible to a researcher's bias. Recently, Scherr & Wittmann [10] demonstrated how a researcher's agenda implicitly "filters" what the student is saying in an interview. Our framework provides an explicit filter through which to examine what a student is saying in an interview.

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Evolution of a Framework

Researchers in the KSU PER Group are working on projects with different goals and use varying degrees of semi-structured interviews. In sharing our findings we discovered that we had all encountered interviewees who made up or changed their responses to interview questions as the interview progressed. Therefore, we decided to re-examine our data from the perspective of the dynamics of student reasoning in the interview.

It is important to emphasize that these data were from five different researchers working independently on their respective projects. Their goals included investigations on students' use of Newton's second law, models of sound propagation, real-world devices, electric circuits and the effect of question order. The students interviewed were from diverse backgrounds (non-science majors to engineering/physics majors) in introductory physics classes ranging from concept-based to calculus-based. Through several deliberations we identified four common elements that formed the basis of our framework.

Elements of the Framework

The elements of our framework emerged through analysis and parsing several interview transcripts to understand the role each word or phrase played in the student's reasoning process. Using this method we identified four elements that were common to all transcripts. These elements are shown in Figure 1. The interconnecting arrows represent all possible reasoning paths followed by students in an interview. The four elements are discussed below.

External Inputs, denoted by {I}, is the input provided by the interviewer such as protocol questions, follow-up or clarification questions, hints or cues. It also includes other materials such as text, pictures, demos, videos, etc. that the student is allowed to use. Typically, a student does not directly control {I}, but rather responds to it. However, a clarification or follow-up question may be prompted by what a student says.

Tools, denoted by {T}, include a vast array of cognitive entities that a student uses in her or his reasoning. Tools can be broadly categorized into pre-existing tools that the student brings into the interview or created tools that a student may construct at an earlier time in the interview and reuse later.

Existing tools include a student's prior experience gained through everyday life or instruction. These tools also include a student's internal knowledge in a dormant state, which includes memorized information such as facts, data, formulae, definitions, rules, procedures, etc.

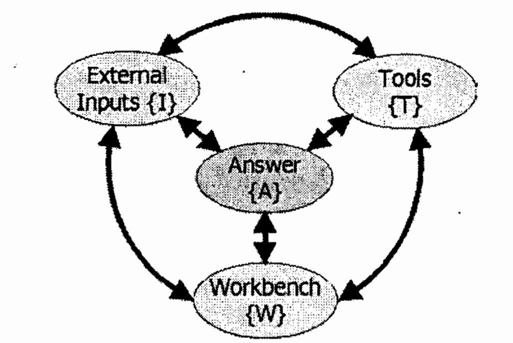

Fig. 1: Four elements connected through all possible reasoning paths.

It also includes knowledge structures of different grain sizes ranging from p-prims or facets of smaller grain size to mental models or theories that have a larger grain size. In addition to learned knowledge and prior experiences, tools can also include a student's epistemology and expectations about the nature of knowledge that is appropriate in a given situation.

Created tools include dynamically constructed knowledge and experiences at an earlier instance in the interview. Typically these might be answers to previous questions that the student refers back to during the interview. It could also include experiences or knowledge of varying grain sizes that a student has acquired while reasoning through previous questions in the interview.

Workbench, denoted by {W}, includes various mental processes used by the student. These processes may utilize {I} as well as activate the existing or previously created dormant knowledge and prior experiences in {T}, such as executing a known rule or procedure.

{W} includes processes that reorganize and restructure knowledge such as assimilation and accommodation. {W} also includes processes in which students combine different pieces of knowledge such as conceptual combination or hybridization. Additionally {W} includes processes which transfer and apply prior knowledge and experiences in new situations such as the processes inherent in analogical, inductive or deductive reasoning. Finally, {W} also includes the process of decision making. Decision making can occur when a student decides that a given analogy or explanation is applicable to the situation at hand. Decision making can also occur in situations when the student has arrived at more than one plausible answer and has to choose between them.

Answers, denoted by {A}, marks the conclusion of the reasoning process. It is important to emphasize that the answer does not necessarily occur at the end of the response given by the student. Sometimes the answer is only an intermediate stopping point. For instance, a student might arrive at a particular {A} and decide to rethink a given question and therefore continue the reasoning process.

Answers can broadly be categorized into three types. A decisive answer is one in which the student arrives at a single conclusion, which could be either correct or incorrect. A student may also give an indecisive answer. This situation can occur when a student has arrived at two or more answers and is unable to choose between them or when a student requests more information from the interviewer. In the latter case {A} will in fact be phrased as a question. Finally, an acceptable {A} could also be one in which the student has no answer, e.g. when she simply says "I don't know," and does not request further information from the interviewer.

Using the Framework

We demonstrate the framework with a specific example in which the student was asked to walk the interviewer through a Force Concept Inventory [11] question (# 18), given the figure (Fig. 2).

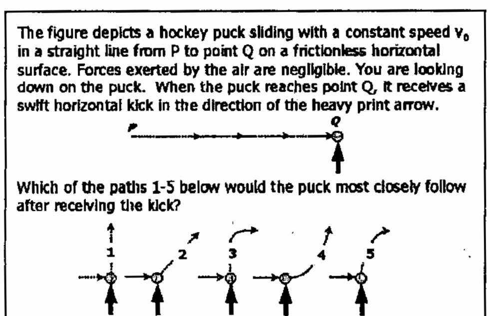

Fig. 2: Figure accompanying interview question.

Coding: The transcript is parsed into words and phrases corresponding to {I}, {T}, {W} or {A}:

Interviewer {I}: Okay, if you can walk me through this [hockey puck] problem (Fig. 2).

Student:

{T} Well, from watching the hockey games, um,

{W} the puck would s-, when it was hit it would stop it's um whatever the horizontal, what appears to be horizontal in this picture, um that speed would stop and it would then move ahead. Um, it completely changes directions,

{A} so I would say it would be number [choice] 1. Um - Yeah that's all I can think of on that one.

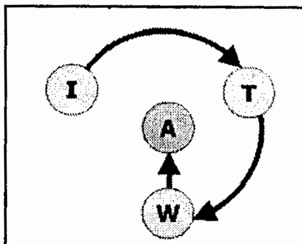

Fig. 3: Reasoning path.

Analysis: When asked the hockey puck question {I}, the student recalls his prior experience (watching hockey games) {T} and applies it to select {W} choice 1 {A} for the path of the puck. The reasoning path is depicted in Fig. 3.

This example was chosen primarily because it clearly demonstrates the mechanics of coding and how the framework enables a researcher to identify various elements. More interesting examples will be discussed in a second paper.

Some Caveats

A few remarks are in order. First the descriptions of various elements in our framework are not exhaustive. For instance {I} could include non-verbal cues such as interviewer's gestures or facial expressions that we did not explicitly include in our framework. Similarly {W} could include several mental processes such as abduction [12] that we have neglected to mention.

Second, the various entities within a given element are not mutually exclusive. For instance, when a student refers to a specific {T}, say prior experience (e.g. pushing a grocery cart), she may also be using a p-prim (motion implies force) which is related to this experience. While she explicitly states the former, she may also be using the latter. Similarly in {W} two or more processes can equivalently describe a students' thinking. For instance, abduction involves decision making.

Third, the boundaries between various elements are often difficult to distinguish. For instance, a mental model that is procedural in nature (e.g. If 'X' then 'Y') could be categorized as either a {T} or a {W}. The use of an element can sometimes be implicit. For instance, answer {A} ("It speeds up because a net force acts on it") implicitly uses a {T} (Newton's II law) although the student does not explicitly state the tool.

Our framework does not characterize a student's reasoning definitively. The inter-rater reliability is about 80%. Our framework is susceptible to a researcher's bias in ways similar to other methods of qualitative research analysis.

Why use our Framework?

The process of coding the transcript forces a researcher to carefully consider what the student is saying without overlooking words or phrases which may have been filtered out by the research agenda. The researcher is urged to look for evidence of each of the four elements, therefore, using this framework alerts the researcher to the absence of one or more of these elements, especially {T} and {W}, thereby enabling her to look past {A} and ask appropriate follow-up questions. By interconnecting the elements, the researcher can carefully trace the effect of various inputs and cues such as a {T} that a student uses when presented with a particular input {I}.

Our framework can be used not merely in the analysis of interview data but also in the planning and design of an interview protocol. Interviewers can use their knowledge of the framework to frame questions that elicit the relevant tools and workbench processes that a student uses. Similarly, by being aware of the framework the interviewer can ask appropriate follow-up questions to elicit these tools and processes.

In the next paper in these Proceedings we present several examples that demonstrate how our framework can identify interesting reasoning paths. We also discuss the implications of our framework as a research tool.

Acknowledgements

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