

## **Implications of a framework for student reasoning in an interview**

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**Abstract:** We discuss the implications of a framework to characterize student reasoning in an interview. Our framework, described in a previous paper, enables a researcher to identify various cognitive elements used by a student during an interview. Here we demonstrate how this framework can help identify reasoning paths used by the students. We also discuss how this framework can be applied to both a coarse and fine grain analysis of reasoning and how it can be used to infer implicit reasoning processes used by a student. We describe the underpinnings of our framework in cognitive psychology.

### **Summary of the Framework**

From our diverse interview data, we have constructed a framework for student reasoning in an interview. Our framework consists of four elements: 1) *External inputs* {I} (e.g. questions, verbal, graphic and other cues) from the interviewer and interview environment. 2) *Tools* {T} (e.g. memorized or familiar formulae, laws and definitions, prior experiences) that the student brings to the interview. 3) *Workbench* {W} encompassing mental processes (e.g. induction, accommodation) that incorporate {I} and {T}. 4) The *answer* {A} given by the student.

### **Some Interesting Reasoning Paths**

Our framework can unearth some interesting reasoning paths used by students, as shown below.

**Analogical Reasoning:** Analogies can be powerful reasoning tools [1]. An analogy involves two main components -- *source* and *target*. In our framework, the target is provided by {I}, however the source is the tool {T} that the student selects. Analogical reasoning involves three processes in the workbench {W}. First is *recognizing* i.e. finding {T}. Second is *abstracting* the structural similarities between source and target. Third is *mapping* these principles from source to target.

In Example 1 below, the student uses a real-world analogy to answer a question about a bike. When asked how the pedals make the rear wheel move {I}, the student uses an analogy of a pulley in an elevator {T} (source). The first process in {W} (recognition) is implicit. The student explicates the other two processes (mapping and abstracting). She talks about the mechanism and how it makes the wheel move via the chain {A}.

**Conflict Resolution:** Cognitive conflict or dissonance [2] can help students learn science [3].

#### Example 1

**Interviewer:**

{I} How does turning the pedals make the rear wheel move? (Real bike provided)

**Student:**

{A} Because it has a chain

{T} it's kinda like a pulley, almost like an elevator in a way, how this is set up.

{W} It just grabs onto this little round thing (a sprocket), but it works like a pulley thing. As this moves it in turn makes this sprocket move which in turn is connected to this, that rotates this as this is rotating.

Piaget's [4] cognitive disequilibrium occurs during assimilation and accommodation (both {W}), when a learner's internal knowledge {T} conflicts with her/his external experience in a discrepant event {I}.

In Example 2 below, when asked to predict how the brightness of two bulbs in parallel will compare to a single bulb {I<sub>1</sub>}, the student answers

#### Example 2

**Interviewer:**

{I<sub>1</sub>} How will they (2 bulbs in parallel) compare now (to one battery and one bulb)?

**Student:**

{A<sub>1</sub>} I still think it won't be as bright as a single bulb

{T<sub>1</sub>} because you still have two bulbs to light.

{W<sub>1</sub>} It will still be less than the first (one battery and one bulb) because you still have energy, you still have to share between two bulbs instead of just one.

**Interviewer:**

{I<sub>2</sub>} So what happened? (Interviewer completed circuit and bulbs light)

**Student:**

{A<sub>2</sub>} It stayed the same.

**Interviewer:**

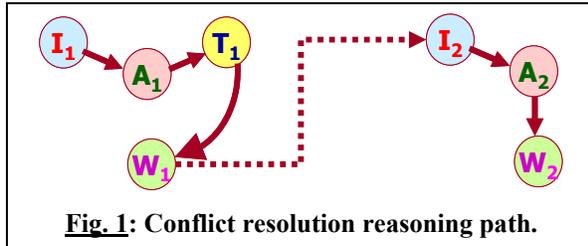
{I<sub>3</sub>} Why?

**Student:**

{W<sub>2</sub>} Well, you just have that constant energy going to each

{A<sub>2</sub>} so it stays the same.

based on a p-prim (more is less)  $\{T_1\}$ , and elaborates  $\{W_1\}$  their answer - less bright  $\{A_1\}$ . The interviewer completes the circuit so that the bulbs light and asks what happened  $\{I_2\}$ . The student answers that they stayed the same  $\{A_2\}$  reasoning that the energy must be the same going to each bulb  $\{W_2\}$ . The tool, which is implied, is denoted by 't'. Fig. 1 shows the reasoning path.



**Metacognition**, or “thinking about thinking,” was first defined by Flavell [5]. Metacognition is often described in terms of two components – *knowledge* and *regulation*. Metacognitive knowledge, a  $\{T\}$  in our framework, refers to self-awareness about one’s own learning. Metacognitive regulation [6] involves mental processes i.e.  $\{W\}$  to monitor cognitive outcomes  $\{A\}$ . Therefore various components of metacognition correspond to the elements of our framework.

In Example 3, a student is asked  $\{I\}$  to explain why sound is softer on the other side of a wall. She starts by assuming  $\{W_1\}$  that sound is a material entity  $\{T_1\}$ , based on which she figures  $\{W_2\}$  that it would be softer on the other side of the wall. Next she alludes to a response to a previous question (“since I said”), now used as a tool  $\{T_2(A_{\text{previous}})\}$ , where she had concluded that sound is *not* a material entity. This belief is her present mental model of sound propagation [7]. Next, the student reflects  $\{W_3\}$  on why this model  $\{T_2\}$  does not explain her experience  $\{T_3\}$ , that sound is quieter on the other side. Finally, she goes back  $\{W_4\}$  to her previous assumption that sound is material, which would explain  $\{T_3\}$ , but she is not comfortable with the idea that sound (“vibration”) is material. So the final answer  $\{A\}$  is an unresolved dilemma. This reasoning path is metacognitive because she engages in self-regulation  $\{W\}$ , monitoring her cognitive outcome -- conflict between assumption  $\{T_1\}$  and model  $\{T_2\}$ ; and tries unsuccessfully to achieve self-consistency.

**Example 3**

**Interviewer:**  
 $\{I\}$  What happens when it [the sound] propagates [through the wall], and what happens when [i.e. why does] it gets quieter?

**Student:**  
 $\{W_1\}$  (Pause) Well, if I would say  
 $\{T_1\}$  it [i.e. the sound] was material,  
 $\{W_2\}$  which I don't think it is ... it would go through here (sketches the path shown below), and it would hit some of these until it'd lose some of its strength.  
 $\{T_2(A_{\text{previous}})\}$  But, since I said it's not material, I'm not sure....  
 $\{W_3\}$  So, maybe I'll have to go back and say that maybe there is something material in it, because ... I don't know why else  
 $\{T_3\}$  it would ... be louder on ...[one] side and quieter on the other side.  
 $\{W_4\}$  [Unless] if it was material ... I'm still having a hard time thinking that, like the vibrations are material, but on the other hand  
 $\{A\}$  I don't know why they, like how this [sound diminishing] would happen if it wasn't material.

**Advantages of Using our Framework**

The framework was constructed from our interview data. Therefore, it can aid in various stages of an interview-based research project. In the research design stage the framework can help focus the overall protocol to better meet the goal of understanding students’ reasoning. Second, it can help researchers design individual interview questions  $\{I\}$  to better elicit the cognitive tools  $\{T\}$  and workbench processes  $\{W\}$  that a student uses. In the research implementation stage, i.e. *during* the interview, the framework can help the interviewer ask appropriate follow-up questions  $\{I\}$  that would urge students to explicate their

reasoning. Finally, in the research analysis stage, the framework can help a researcher glean overall trends in a student's reasoning across several questions, or to analyze a transcript at multiple grain sizes.

In Example 4 below, the student is asked the number of gears that a bike has. The transcript can be analyzed at two grain size levels. We can use a broad brush to see global trends in the data and large grain size knowledge elements (e.g. mental models). We can also use a finer brush to see details that emerge from the data such as small grain size knowledge elements, (e.g. resources) or transfer, selection of various tools and the back and forth trying unsuccessfully to decide between different answers.

**Interviewer:**  
 {I} So how many gears do you think this bike has?

**Student:**  
 {W<sub>1</sub>} Well, my first guess  
 {A<sub>1</sub>} is a 10 speed  
 {T<sub>1</sub>} because this is the size they usually are  
 {A<sub>2</sub>} but maybe it's a three speed.  
 {T<sub>2</sub>} It's got three little thingies.  
 {W<sub>2</sub>} If I was going to use reason  
 {A<sub>2</sub>} I guess I'd say three  
 {W<sub>1</sub>} if I were going to use a guess  
 {A<sub>1</sub>} I'd say a 10 speed.

**Example 4: Analysis of transcript at two grain sizes**

Our framework can be applied in two ways. First, it can be used to understand what students say, by categorizing various words and phrases in the transcript as {I}, {T}, {W} or {A}. Second, it can be used to *infer* what students think. To do so researchers make informed speculations about what students are *thinking*. Thus, this mode of application is highly susceptible to researcher interpretation and bias. In either case, it is advisable to use standard reliability measures such as inter-rater reliability while using the framework. Example 5 below demonstrates how the framework can be used in the two ways described above.

In Example 5 below, students are asked to explain how sound propagates through the wall. By parsing the student's response one can identify {W}, {T} and {A} as they chronologically occur in the transcript. A researcher may also try to infer that the student uses analogical reasoning. Analogical reasoning involves three {W} recognizing and selecting a target {T}, abstracting the structural similarities between source and target, and mapping similarities from source to target. The first of these processes is somewhat evident from the transcript. The other two are inferred, based on our theoretical understanding of analogical reasoning. Therefore the reasoning path goes back to {W} (for abstracting and mapping) before terminating at {A}.

**Example 5: Applying the framework to...**

What students say	What we <i>infer</i> they think
{I} Asked how sound gets to the other side of a wall. {W} "Well, I would say that to me it is somewhat like" {T} "a maze for the sound" {A} "it just kind of works its way through until it gets to the other side."	Student recognizes {W} that the situation is analogous to a maze {T} for the sound. She applies the analogy to deduce {W} that air works its way through until it gets to other side of the wall {A}.

There was no attempt made in the inferential analysis above to separate the abstraction and mapping processes in {W}. This demonstrates that although the framework can be used to bridge data with theory, use of the framework must ultimately be grounded in the data.

**Connections with Cognitive Psychology**

It may be evident from the nomenclature of various elements that our framework uses the metaphor of a workshop. The input {I} is analogous to the work order given to a worker (e.g. build a chair). The tools {T} are analogous to the tangible implements (e.g. saw) that the worker uses, as well as her skills in performing the task. The workbench {W} is analogous to the work area (e.g. work table) as well as the fabrication processes. The answer {A} provided by the student is analogous to the finished product (e.g. chair) constructed by the worker.

Our framework also has underpinnings in cognitive psychology [8]. The sensory input and response are analogous to {I} and {A} respectively. The short-term (working) memory, and the mental processes occurring therein are analogous to {W}. The long-term memory and information are stored therein are analogous to tools {T}.

Our framework also shares commonalities with a metaphor in cognitive psychology – the computer. Input {I} is analogous to input devices (e.g. keyboard). Answer {A} is analogous to output devices (e.g. monitor). Tools {T} are analogous to stored information (data, software etc.) on the hard drive. Workbench {W} is analogous to active processes in a processor or RAM.

### Other Issues

Our framework attempts to characterize the dynamics of student reasoning in an interview. However it tends to focus exclusively on cognitive issues. It does not address other issues relevant to interviewing, such as the student’s epistemological stance or emotional state while participating in the interview. Wittmann and Sherr [9] have demonstrated that a student’s epistemological stance can mediate and constrain a researcher’s access to her/his reasoning.

A student’s epistemological beliefs may be characterized as tools {T}, however our framework does not explicitly account for such non-cognitive elements mediating an interview. Nevertheless, our framework does alert a researcher to the presence of these issues.

In the first segment below, the student says that

■ Student is asked what gears are on a bicycle.  
**Student:** Um, I don’t really have a **good scientific definition** but it’s just they’re like different modes ...

■ Student is asked to explain why he assumes a charged sphere in an E-field acts like a point charge.  
**Student:** I wasn’t thinking about it in the sense of having - **I should read the chapters** – um, if it has the same charge, I think you can assume it’s a point charge...

she needs to be “scientific”. Similarly the student in the second segment indicates that he should have “read the chapter.” In both of these cases it is likely that these epistemological beliefs constrained the student’s responses throughout the interview.

Applying our framework entails an attention to detail that would alert the researcher to statements such as those made below, which may reflect a student’s epistemological stance. Such statements may have otherwise gone unnoticed in the analysis.

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