Conceptual Dynamics in Clinical Interviews

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Abstract. One of the main tools that we have for the study of student science conceptions is the clinical interview. Research on student understanding of natural phenomena has tended to understand interviews as tools for reading out a student's knowledge. In this paper, we argue for a shift in how we think about and analyze interview data. In particular, we argue that we must be aware that the interview itself is a dynamic process during which a sort of conceptual change occurs. We refer to these short time-scale changes that occur over a few minutes in an interview as *conceptual dynamics*. Our goal is to devise new frameworks and techniques for capturing the conceptual dynamics. To this end, we have devised a simple and neutral cognitive framework. In this paper, we describe this framework, and we show how it can be applied to understand interview data. We hope to show that the conceptual dynamics of interviews are complex, but that it nonetheless feasible to make them a focus of study.

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REVISITING THE "COHERENCE" QUESTION

An enormous amount of research has focused on the intuitive conceptions that students possess about science topics prior to formal instruction in those topics. Despite this significant body of research some of the most important questions are still in dispute. Perhaps the most fundamental of these questions is the coherence question. On one side of the debate are researchers that believe that students possess coherent models or even theories prior to instruction [1, 2] . On the other side of the debate are researchers that believe students possess a large number of pieces of knowledge that are employed in a sometimes inconsistent manner [3].

Although this question is still in hot dispute, we believe that, on one level, the answer to the coherence question is obvious. That answer is: It depends. It depends on…

1. **… the person and domain**. It simply must be the case that some individuals have coherent understandings in a domain while others do not, due to differences in prior experiences and other cognitive variables, such as age.
2. **… how knowledge is elicited**. The conditions and techniques for eliciting knowledge will affect what coherences we can observe in reasoning. Slight variations in interviews can produce substantial changes in apparent coherence of student understanding [4-6].
3. **…our definition of 'coherence.'** Different meanings of coherence have been applied, and they are, at times, in conflict. For example, diSessa and colleagues [7] have contrasted what they call *contextual* and *relational* coherence.

Given these dependencies, we believe that a change in tactic is necessary. We should not ask, generally speaking, whether students have coherent models. Instead, our goal must be to map out where, when, and what kinds of coherences are generated.

A FOCUS ON THE DYNAMICS OF CLINICAL INTERVIEWS

The above change in stance has many implications for research, some of which are methodological in nature. Research on student understanding of natural phenomena has tended to understand interviews as tools for reading out a student's knowledge. We believe it is more appropriate to think of coherences as arising throughout the course of an interviewing interaction. Thus, we must be aware that the interview itself as a dynamic process during which a sort of conceptual change will occur. We refer to these short time-scale changes that occur over a few minutes in an interview as *conceptual dynamics*. The goal of our

project is to devise new frameworks and techniques for capturing conceptual dynamics in interviews.

To understand the challenge that we face as researchers, consider the cartoon shown in Figure 1, which depicts a short exchange in a clinical interview. The person on the left in each pane is a student, and the person on the right is the interviewer. The shapes inside the student's head represent the knowledge resources that the student has available.

In the first pane, the interviewer asks a question. The student then responds in the second pane, drawing on a subset of his knowledge resources in order to construct an answer. In the third pane, the interviewer asks a follow-up question. Then, in the fourth pane, the student draws on a different subset of his knowledge resources, and constructs a different response. As cognitive researchers, we are interested in the knowledge possessed by the student – the shapes inside his head. But, as data, all that we have available are the behaviors of the interviewer and the student, which include their utterances, gestures, and any drawings that they make.

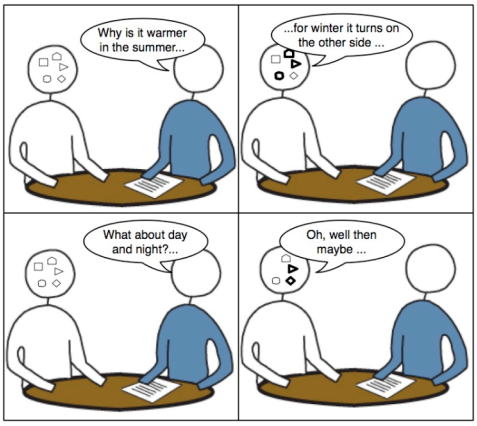

FIGURE 1. An exchange in a clinical interview.

THEORETICAL FRAMEWORK

Given the situation depicted in Figure 1, the challenge we face is to "see through" the interview to the knowledge possessed by the student. As researchers, we must seek to produce an analysis of the knowledge resources that, in part, generate the interview dynamics we observe. One challenge in conducting such an analysis is that there are many elements and types of knowledge employed during a clinical interview. However, we believe it is possible to make progress using a relatively simple and neutral framework. The major constructs of this framework are:

Nodes: We think of knowledge as consisting of a large number of elements we call *nodes*. We intend our notion of node to encompass mental elements of many different types and at multiple levels of abstraction.

Mode: A *mode* is a recurrent pattern of nodes that is activated for a particular class of cognitive tasks. The same node may participate in more than one mode. (Refer to Figure 2.)

Dynamic Mental Construct (DMC): A *DMC* is a constructed explanation that is produced by the reasoning that occurs within a mode. It can be highly context sensitive and it may have only momentary stability.

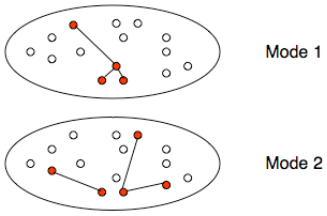

FIGURE 2. The same node may participate in more than one mode.

In terms of this framework, student reasoning during an interview is understood as follows: The interviewer asks a question and this leads to the activation of a mode. The student then reasons within this mode, assembling the nodes into a DMC (a model or answer to the question that was asked). The interviewer then asks another question. This can lead to more reasoning within the same mode, or to the activation of another mode.

DATA SOURCES

We have conducted ~160 clinical interviews with middle school students on a variety of science topics including: human biology, chemical reactions, optics, climate, energy transfer, and seasonal temperature variation.

AN EXAMPLE: LESLIE ON THE SEASONS

We now present a short excerpt to illustrate some of the interview phenomenology that we seek to understand and analyze. We present this to demonstrate conceptual dynamics and to show our framework in use. In this excerpt a student, Leslie, is asked to explain the seasons – why it is warmer in the summer and colder in the winter. The result is an extended response, over which her reasoning gradually unfolds.

TABLE 1. Analysis of the excerpt.

	Nodes	Dynamics	Current DMC
(1)	• Daylight Savings Time • Days are longer in the summer • More source ⇒ more effect	Skimming the mode throwing out first relevant elements. First assembly of a fledgling DMC.	Days are longer in the summer. Longer days mean more daylight which makes it warmer.
(2)	• Axis (word) • Earth moves	Skimming the mode throwing out relevant knowledge	Earth's movement and axis somehow are related to the seasons.
(3)	• Different seasons in different locations. • India is hot • India is near the equator • The equator is hot • Sun is a source	More skimming of the mode. She strikes out in a new direction now construct a DMC related to climate phenomena.	It's colder up north because there's less sun, warmer near the equator because there is more sun.
(4)	• Image of sunny winter wonderland • Snow/ice up north • Snow/ice are cold • More source ⇒ more effect	Leslie recalls a vivid image of a scene that shows a lot of snow but also a lot of sun. The cuing of this new node leads to a shift. Note how she corrects herself in mid sentence.	It's colder up north because of the snow and ice.

Interv. *First thing I want to know is why is it warmer in the summer and colder in the winter?*

Leslie **(1)** Well, umm, you know times savings? … daylight savings time in the summer we have more time, like, with, like, daylight and that's why it gets warmer. **(2)** And with the circulation of the earth and the axis that it's on just has to do with like summer and winter. **(3)** And it depends on where we are on the earth, like if you look at, umm, India, it's toward the equator, you know? So it's like always hot. So if you go up north then it gets colder **[4]** because there's just, like, I can't really say less sun, but it kind of has to do with that and there's just a lot of snow and, like ice cause it's colder up there.

Leslie's utterance is broken into four chunks, and our analysis of each of those chunks is given in Table 1. In the first chunk, Leslie begins by mentioning "daylight savings time," and she then constructs her first fledging DMC: days are longer in the summer, and longer days mean more daylight, which makes it warmer. In the second chunk, she just mentions two nodes – *Axis* and *Earth moves* – without immediately incorporating either of them into a DMC. We believe that her mention of "axis" here signals no more than that she knows that this word is somehow relevant to explaining the seasons.

In chunk (3), Leslie seems to strike out in a new direction. She begins by saying "it depends on where we are on Earth." Then she goes on to construct a DMC that is more relevant to climate variation with latitude than to the seasons. She says, essentially, that it's colder up north because there is less sun and warmer near the equator because there is more sun. In this chunk she also specifically mentions India as a location that is both hot and near the equator.

Finally, in chunk (4), Leslie seems to interrupt and correct herself, contradicting the DMC she constructed in chunk (3). She starts to say that it's colder up north because there is less sun, but then she says, instead, that it is colder because of snow and ice: "I can't really say less sun, but it kind of has to do with that and there's just a lot of snow and, like ice cause it's colder up there." As the interview proceeded, it became clear what Leslie was thinking here and why she corrected herself. It seems that she has a vivid memory of seeing photographs of a sunny "winter wonderland," showing a landscape covered in snow, but illuminated with bright sunlight. Based on this image, she concluded that cold regions could still have a great deal of sunlight.

We want to highlight a few features of the brief analysis summarized above. First, one might have thought that it would be extremely difficult to see conceptual dynamics as they unfold during an interview. But we hope that this excerpt makes it clear that, at least in some cases, it is possible to see student reasoning as it unfolds. Within this brief episode, we can see Leslie's thinking as it. Furthermore, although the dynamics are complex, they are not completely unfathomable; it is possible to make some reasonable guesses about what Leslie is thinking and why.

Finally, we want to emphasize the importance of attending to as much of Leslie's knowledge as possible, and even to relatively idiosyncratic elements of her knowledge. Many analyses of student reasoning during interviews reduce their knowledge to one of a

small number of mental models. But, in Leslie's case, it is clear that her reasoning is being driven by more narrow and idiosyncratic elements of knowledge, such as her knowledge that India is hot, and her image of a sunny winter wonderland. If we were to ignore these more idiosyncratic elements of knowledge then we would not be in a position to understand why Leslie's reasoning unfolds as it does.

PATTERNS OF CONCEPTUAL DYNAMICS IN INTERVIEWS

Clinical interviews vary greatly in character, and can unfold in a complexly variable manner. However, there are some rough patterns and regularities that can be observed.

Mode skimming. When a question is first asked and a mode activated, sometimes a student will skim the surface of the mode. They will just list out ideas that might be relevant, without any attempt to fit them together into a DMC.

DMC construction and model building. Once some relevant nodes are selected, a student might engage in an extended process of trying to fit together those nodes into a DMC that has the desired properties.

DMC shifts. Many kinds of interviewing events can lead to a shift in the current DMC. These can be student-driven or interviewer-driven. Sometimes, as in the interview with Leslie, these shifts can occur just as the student's thinking unfolds. But they may also occur as a result of more dramatic events, such as a challenge from an interviewer. They may also occur when a student remembers a new and potentially relevant piece of knowledge, such as Leslie's image of a snowy winter wonderland.

Mode shifts. There can be a shift in the mode that is active, leading to a more dramatic change in DMC.

Attractor DMCs. Some DMCs can act as attractors for students; once discovered, these DMCs will be particularly appealing. For example, in the case of the seasons, one prominent explanation is what we call the closer-farther explanation. This explanation goes as follows: The Earth orbits the sun in such a way that it is sometimes closer to the sun and sometimes farther from the sun (perhaps an ellipse). Summer corresponds to the time when the Earth is closer, and winter corresponds to the time when it is farther [e.g., 8, 9]. This explanation, though incorrect, has many pleasing properties. Many people have heard that the Earth's orbit is elliptical. The fact that this explanation incorporates this technical bit of information means that it might acquire, by association, some of the weight of authority. And there is much that this explanation can predict that *is* correct. In particular, it predicts that the cycle of the seasons will be repeated with a period of one year, and it links this cycle to the Earth's orbit.

CONCLUSION

One of the main tools that researchers have for the study of students' science conceptions is the clinical interview. In this paper, we argued for a shift in how we think about and analyze interview data. In particular, we argued that it is important that we understand interviews as dynamic interactions, and that these interactions must themselves be a focus of our study. To this end, we described a simple and neutral cognitive framework, and we showed how that framework can be applied to understand interview data. We hope that, as a result, we have shown that the conceptual dynamics of interviews are complex, but it is nonetheless feasible to make them a focus of our analysis.

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