

Using clinical interviews to study science knowledge and learning

This is an extremely rough draft!!!

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Introduction

The Center for Curriculum Materials in Science (CCMS) is concerned with the design of novel science curricula. Certainly, as a center, we share an interest in being able to say as much as possible about what students learn from the curricula that we design. Given any particular curriculum, we like to be able to answer these questions: What is the knowledge with which our target population enters instruction? How is that knowledge changed by instruction?

As researchers and educators, we have quite a few tools at our disposal for capturing the learning of our students. These tools include, for example, written tests and structured interviews, each with their own set of trade-offs. Written tests are effective for assessing learning over a large number of students, but more often than not, provide just a tiny glimpse into how the structure and organization of knowledge in a student's mind has changed. A structured interview can sometimes do a little better, albeit usually with a smaller sample. Still, that too is often limited as an instrument, often because of a priori assumptions about the coherence of student knowledge that influence how the protocol was designed. However, the *clinical interview* has played a central role in the methodological toolboxes of science education researchers. Here we are using the phrase "clinical interview" to refer to an interview that is somewhat open-ended, and where the interviewer has the freedom to ask follow-up questions and to explore, on-the-fly, based on the responses given by the student (Clement, 19xx; Ginsberg, 19xx). We are very aware of the limitations of clinical interviews. The very freedom that gives the clinical interview its power, also poses difficulty when we seek to use it as an instrument of research.

This paper will describe work done by the Conceptual Dynamics Project (CDP), an NSF-funded¹ project housed at Northwestern University. One goal of CDP has been to develop theoretical and methodological tools to increase the usefulness of clinical interviews for science education research. Underlying this effort is a core stance that guides our work. We believe that it is not sufficient to conceive of interviews as tools that "read out" student knowledge in a straightforward manner. It is not, in general, the case that a student possesses models, for example, and that an interview can read out that model. Instead we must understand each clinical interview as an unfolding process, driven by the entirety of student knowledge and the particular way that the interview unfolds. If we want to read out student knowledge from an interview, then we need to be able to see through this unfolding process to the knowledge that, in part, generates the process.



Figure 1. The unfolding process of an interview.

¹ *The Conceptual Dynamics Project: NSF, grant #0092648.*

A simple cartoon can perhaps help to clarify what we have in mind (refer to Figure 1). This cartoon depicts a few minutes from an interview. On the left in each pane is the student, and on the right is the interviewer. The shapes in the student's head are intended to represent knowledge resources possessed by the student. In the first pane, the interviewer asks a question. Then, in the second pane, the student has drawn on some subset of her knowledge resources (indicated by the highlighted shapes) in order to answer the question. In the third pane, the interviewer asks a follow-up question. Then, finally, in the fourth pane, the student gives another answer, drawing on a different subset of the knowledge resources she has available.

As researchers concerned with student knowledge, we are concerned with getting at the knowledge resources possessed by the student – the shapes – and how these resources change. But the data we have available are just the visible attributes of the interview, namely: any statements made by the interviewer and the student, their gestures, and any drawings that they make.

The central point of this paper is that, fortunately, these “unfolding processes” are not impossible to fathom. We believe it is possible to see students reasoning and constructing their explanations in response to an interviewer's questions, and we believe we can make reasonable guesses about what knowledge resources they are drawing upon.

Our goal in this brief paper is very limited. Our intent is only to give the reader a sense for what the “unfolding processes” look like, and to begin to argue that it's possible to get a handle on these processes, and the knowledge that generates them. (For a more complete explication of our approach see XX.)

Some background

To illustrate our program we will draw on data and analysis from the work of the Conceptual Dynamics Project. As part of CDP, we conducted interviews with middle school students on a variety of science-related topics, mostly in the context of curricula developed by researchers at Northwestern University. Here, we will draw on a small subset of those interviews, in which middle school students were asked to explain the seasons. We have approximately 40 total interviews on this topic.

In our interviews about the seasons, we always began by asking “Why is it warmer in the summer and colder in the winter?” Then the interviewer would ask different follow-up questions, depending on what the student said. The interviewer had the freedom to improvise; however, in planning our interviews, we attempted to anticipate as many student responses as possible, and we devised follow-up questions for each of those responses.

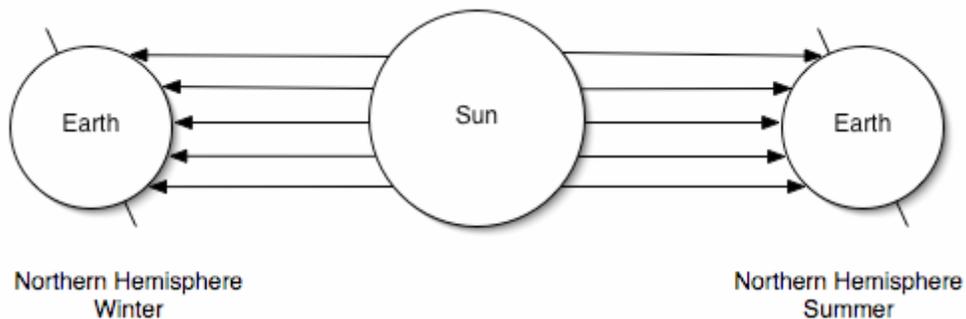


Figure 2. Explanation of the seasons.

The diagram in Figure 2 is intended to briefly remind readers of the standard explanation for the seasons. The left side of the diagram shows the Earth's position when it is winter in the northern hemisphere. Because the northern hemisphere is tilted away from the sun, that hemisphere receives less direct sunlight and thus is colder. In contrast, when it is summer in the north, that hemisphere is tilted toward the sun, and thus receives more direct sunlight.

A first example episode

In this section, we will present a first example episode, drawn from an interview with a student we call Ali.² Our purpose, in this section, is to introduce the reader to the unfolding behavior often exhibited in clinical interviews. The excerpt begins when the interviewer asks the initial question and Ali responds.

1. Interv. The question is why is it warmer in the summer and colder in the winter?
That's what I want to know.
2. Ali Because of the su- because of the Earth's movement.
3. Interv. Mm hmm
4. Ali Er- yeah, the axis of the Earth.
5. Interv. So how exactly does that work? How does it make it-?
6. Ali Well, like when the Earth goes around the sun it's kind of tilted. It turns too
<rotates finger> like every 24 hours it turns and so that changes our seasons
7. Interv. But how does-
8. Ali So when it's away from the sun it's colder and when it's like directly in front
of the sun it's hot

In Line 2, Ali gives her first brief response. She says that the seasons has something to do with the sun and the Earth's movement. But there is no reason, at this point, to suppose that she has much of this worked out – she may not have a clear idea of exactly how the Earth moves or how this is relevant to the seasons.

The interviewer then responds with what is essentially a little request to elaborate. In response, Ali mentions a few other tidbits of information in Line 6. She says that the Earth goes around the sun, is titled, and that it rotates every 24 hours. The mention of tilt here is tantalizing but, again, it's not clear that Ali has any particular explanation in mind. Finally, in Line 8, Ali says “when it's away from the sun it's colder and when it's like directly in front of the sun it's hot.” From this, it's not entirely clear what Ali means by “when it's away” and “directly in front.” It's also not clear if this is, yet again, something new, or if it's an elaboration on what Ali was saying in Line 6.

This was just a brief excerpt, but you can see some examples of the sort of phenomena that are our focus. This illustrates one way (but not the only way) in which our interviews unfolded just after the posing of the initial seasons question; the student would cast about, throwing out a number of potentially relevant little nuggets. Roughly the feeling is that the student is searching among these nuggets for some pieces that might fit together to form an answer to the question.

The mode-node framework

Hopefully, the brief excerpt in the preceding section has suggested, to the reader, that it possible to get a handle on the unfolding processes in a clinical interview about the seasons. Now we will describe the theoretical framework that we have been employing in order to begin to capture these processes. Our approach, is to see how far we can get while employing as simple and neutral a framework as possible. We thus devised a theoretical framework that introduced a small number of types of theoretical entities, and that made few assumptions about those entities.

First, we assume that student knowledge consists of a complex ecology of mental elements of diverse types and at multiple levels of abstraction. As a way to make progress, we use a single word for all such elements of knowledge: we call them all *nodes* (refer to Figure 3).

² All student names are pseudonyms.

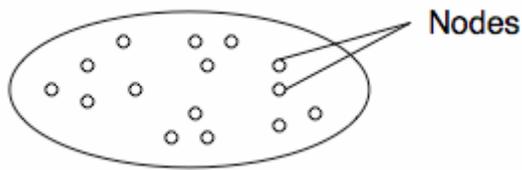


Figure 3. Nodes

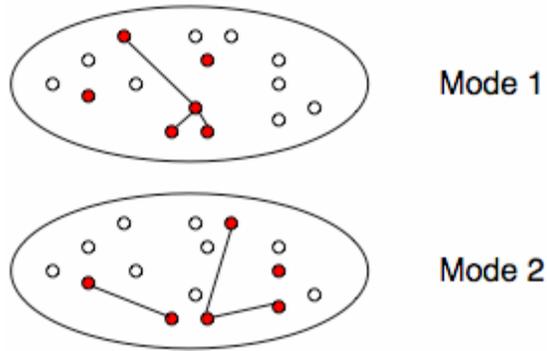


Figure 4. Modes

Our second theoretical construct is what we call a *mode*. A mode is a recurrent pattern in the activation of nodes associated with some cognitive task or function. The idea is that if you give one kind of cognitive task, you'll get one set of nodes drawn upon. If you give another cognitive task, you'll get another patterns of nodes drawn upon (refer to Figure 4).

Our last theoretical construct is what we call the *dynamic mental construction* (DMC). The DMC is the changing explanation or model that results from reasoning by a student within a given mode. So overall the idea is that (1) the interviewer asks a question, (2) this results in a mode being activated so that a set of nodes is drawn upon, and then (3) some reasoning happens from these nodes and results in the construction of a DMC.

Applying the mode-node framework

The program is to apply the mode-node framework, described in the previous section, to help us understand the sort of unfolding process we saw in the interview with Ali. To that end, we created a catalog of nodes for the seasons interview, with the idea that we could code all of the interviews on a line-by-line basis. That catalog had 109 nodes in 14 categories. These 109 nodes are of very diverse types. For example, there are very content-specific and fact-like nodes, such as *equator-is-hot*. There are also very general explanatory schemas, such as *effects-die-away*.

In other papers, we explain how we arrived at this set of nodes, including the problems we encountered (xxrefs). In the end, the bottom line is that this whole exercise provides, for each interview, a skeleton on which we can hang our more interpretive analyses of interview dynamics. In what follows, we will avoid discussion of these details, and instead we will attempt only to provide the reader with a sense for the gist of this type of analysis.

Applying the mode-node framework to the Ali excerpt

Now we describe very briefly an analysis of the Ali excerpt using the mode-node framework. The excerpt began with the interviewer asking the initial question, and Ali responding, in Line 2: "Because of the sun, because of the Earth's movement." This implicates, among other nodes, the *Earth moves*, *the sun is a source*, and the general reasoning schema *movement causes change*.

<p>Nodes</p> <ul style="list-style-type: none"> • Earth moves • Sun is a source • Movement causes change 	<p>1. Interv. The question is why is it warmer in the summer and colder in the winter? That's what I want to know.</p>
<p>Fledgling DMC Somehow the movement of the earth, probably</p>	<p>2. Ali Because of the su- because of</p>

in relation to the sun, is responsible for the seasons.	the Earth's movement.
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In terms of dynamics, Ali is beginning to skim through a mode, pulling out relevant knowledge. In the process, she has begun to construct a fledgling DMC, an early and very vague backbone of an explanation. This DMC says only that somehow the movement of the earth, probably in relationship to the sun, is responsible for the seasons.

In response to this initial answer, the interviewer only says “mm-hmm.” Ali then says “the axis of the Earth.” We believe that, at this point, Ali is still just skimming her mode, and she is throwing out a word – “axis” – that she somehow knows is relevant to this type of question.

Nodes • Axis (word)	3. Interv. Mm hmm 4. Ali Er- yeah, the axis of the Earth.
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Once again, in Line 5, the interviewer asks for elaboration. Ali responds by throwing out still more potentially-relevant information. “Well, like when the Earth goes around the sun it's kind of tilted. It turns too like every 24 hours it turns and so that changes our seasons.” We code her utterance as in part expressing elements of a more elaborate model. She knows that the Earth is tilted, that it rotates and orbits the sun. She also mentions that a rotation takes 24 hours. Furthermore, the same general explanatory schema – *movement causes change* – underlies the whole explanation.

Thus, in response to a request for elaboration by the interviewer, Ali is continuing to skim information out of her mode. Often the purpose of additional mode skimming is to go through the nodes that were expressed and to try and find pieces that will fit together into an explanation. However, in this case, Ali doesn't really change her DMC. At the end of Line 6 she still has the basic explanatory structure she started with – the earth moves and somehow this changes the seasons.

Nodes • Earth structure model: ○ Earth is tilted • Earth movement model: ○ Earth rotates ○ Earth orbits the sun ○ 24 hour rotation • Movement causes change Fledgling DMC Same vague DMC	5. Interv. So how exactly does that work? How does it make it-? 6. Ali Well, like when the Earth goes around the sun it's kind of tilted. It turns too <rotates finger> like every 24 hours it turns and so that changes our seasons
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Finally, the interviewer again hints that he is looking for elaboration and Ali says “So when it's away from the sun it's colder and when it's like directly in front of the sun it's hot.” The nodes we code here are *sun is a source* and *toward is stronger, away is weaker*. At this point, it seems that Ali's DMC has been refined, at least a little; it has shifted from something very vague to something a little less vague. When the Earth is toward the sun it's hotter and when it's away it's weaker.

Nodes • Sun is a source • Toward is stronger, away is weaker Fledgling DMC DMC shifts from very vague to less vague	7. Interv. But how does- 8. Ali So when it's away from the sun it's colder and when it's like directly in front of the sun it's hot
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Of course, at this point it is not at all clear what Ali means by “toward” or “away.” But as the interview continued, she eventually expressed a very clear meaning. As shown in Figure 5, she explained that summer will be experienced by the side of the Earth that is facing the sun, while the opposite side, which faces away, will experience winter.

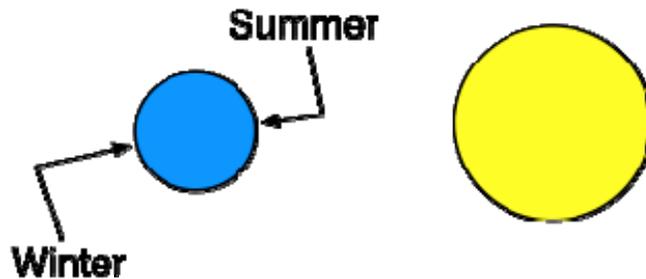


Figure 5. Ali's toward-away explanation.

In our analysis of the brief excerpt, we have attempted to give the reader a taste for the kinds of dynamics we pay attention to in clinical interviews, and how we have begun to make sense of those dynamics in terms of our framework. We've seen that the dynamics can happen fast. We only looked at the first eight utterances in a transcript, and some of these utterances were very brief. But we nonetheless believe it is possible to understand these dynamics. It is possible to see Ali pulling out pieces and beginning to fit those pieces together. She is skimming her mode, looking for relevant elements of knowledge; she is beginning to construct a DMC, and is beginning to refine that DMC in response to pressure from the interviewer.

A second excerpt: Angela

We will now present one additional example in order to illustrate some different interview dynamics. Above, we explained that Ali ended up with a “toward-away” explanation of the seasons; summer is experienced in a part of the earth that faces toward the sun, and winter is experienced in a part of the Earth that faces away from the sun. Another prominent explanation given by the students we interviewed is what we call the “closer-farther” explanation. Here, the idea is that the Earth orbits the sun in such a way that it is, at some times, closer to the sun, and sometimes farther from the sun. Summer is experienced when the Earth is closer, and winter when it is farther away. (Refer to Figure 6.)

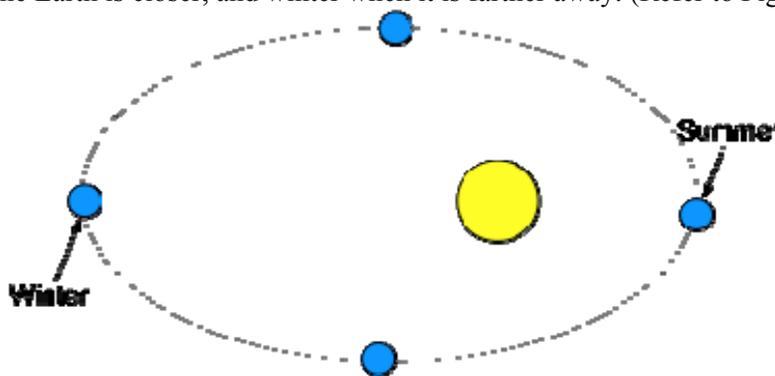


Figure 6. The closer-farther explanation.

In the following excerpt, a student Angela begins by immediately giving a closer-farther explanation.

1. Interv. I want to know why it's warmer in the summer and colder in the winter.

2. Angela That's because of the sun is in the center and the Earth moves around the sun and the Earth is like at one point in the winter, it's like farther away from the sun and towards the summer it's closer it's near, towards the sun.

It is clear that the character of what is going on here, at least initially, is very different than what we saw in the interview with Ali. There is no groping around for an explanation; Angela answers immediately and her explanation is very clear.

However, when a student gave the closer-farther explanation, our interviewer would eventually follow up with a standard challenge; we would point out that this model has a problem with explaining why it can be winter in one part of the world, when it is winter in the U. S. (This fact is apparently familiar to the middle school students we have interviewed.)

When Angela was challenged in this way, she responded as follows.

3. Interv. Mm hmm, okay. So that makes a lot of sense. One thing I wanted to ask you though about was, one thing that you might have heard that at the same time, and you can tell me if you've heard this, when it's summer here, it's actually winter in Australia
4. Angela Mm hmm
5. Interv. Have you heard that before? So I was wondering if your picture the way you drew it can explain that or if that's a problem for your picture.
6. Angela Umm, I need another picture.
7. Interv. So is that a problem for you picture?
<Interviewer. hands Angela a new sheet of paper.>
8. Angela Yeah, that is. Yeah, I remember that now cause um it's like as the Earth is rotating, as it's orbiting, it's rotating too, I guess I don't understand it.
9. Interv. You're saying as the Earth is going around here, it's doing what?
10. Angela It's like spinning, cause it's going like <Angela rotates her index finger>, that's how it's day and night too
11. Interv. Spinning like a top?
12. Angela Yeah
13. Interv. Okay
14. Angela So, yeah, I guess I really don't understand it that much...Yeah, I have heard that, cause I was supposed to go to Australia this summer but it was going to be winter when I was going, but there, winters are really warm.

Apparently Angela sees the problem with her explanation and she is willing to reconsider it. Now the character of the interview is closer to what was observed in the interview with Ali. Angela is trying to assemble what she knows into a consistent explanation.

It is worth noting that part of the reason that Angela finds the interviewer's challenge compelling is that she herself, is planning a trip to Australia. She says, in Line 14, "Yeah, I have heard that, cause I was supposed to go to Australia this summer but it was going to be winter when I was going." This is important because it illustrates how the unfolding process in an interview can be contingent on highly idiosyncratic knowledge, specific to individual students. If we want to understand how reasoning unfolds in episodes of this sort, we cannot ignore this sort of less central knowledge.

Before concluding this paper, we want to comment on what, for us, are some interesting properties of the closer-farther explanation. First, the closer-farther explanation is substantially incorrect. It fails to explain some of the most important phenomena associated with the seasons. However, it integrates just enough information to be compelling, and it does so with a pleasing simplicity. Because of these pleasing properties, the closer-farther explanation can act as something akin to an attractor for students. A student reasoning about the seasons might discover this explanation and think, on some level, “this has to be right.”

Thus, relatively coherent explanations might appear across students, not because many students enter the interview with that explanation. Instead, they may appear because of some properties of the explanation themselves. If an interviewer asks the right sort of question, and a student has the right background knowledge, then the unfolding process of an interview might tend to evolve in the direction of such an “attractor” explanation.

Interview dynamics, more generally

In the above example, we have provided the reader with just a taste for the kinds of dynamics we have seen in our interviews.

- We saw a student skimming a mode.
- We saw DMC construction and refinement, sometimes in response to pressure from an interviewer.
- We saw that, in some cases, a mode can be activated that has a well-established explanation. That appeared to be the case for Angela, although her explanation was not correct.
- There can also be shifts in the DMCs constructed by a student that are more dramatic than simple refinement. These can be student-driven or driven by the interviewer.
- There can also be shifts in the entire mode that is activated. However, we understand most student reasoning about the seasons as occurring within a single mode.

Conclusion

In this short paper, we have described some of the work of the Conceptual Dynamics Project that is concerned with developing theoretical and methodological techniques for improving the usefulness of clinical interviews. We emphasized the importance of treating interviews as dynamic processes. We also hope to have begun to convince the reader that these processes are not entirely inscrutable; it is possible to see students reasoning and constructing their explanations in response to interviewer questions, and it is possible to make reasonable guesses about the nature of the knowledge resources that students are drawing on.

References