A Continuum of Knowledge Structures in an Observation-Based Field Geology Setting

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Abstract: Learning to make scientific observations can be challenging for learners and has sometimes been viewed as unproblematic in instruction. Using the theoretical framework of Knowledge-in-Pieces we examine the structures of learners' localized knowledge systems as they observed rock outcroppings. We document that along an observation-based geology learning trajectory, learners activate localized knowledge systems that exhibit varying levels of coherence and fragmentation, and quantity and relevance of the perceptual information.

Background and theoretical framework

Scientific evidence is central to classroom inquiry and observations are key to children's investigations and explanations, yet, children can struggle with observing unfamiliar phenomena (Eberbach & Crowley, 2009), and systematic observation of unfamiliar phenomena has often been underestimated by educators and researchers who mistakenly cast observation as an everyday skill (Chinn & Malhotra, 2001). Comparably, professional scientists engage in complex observation tasks where they observe detailed patterns based on their disciplinary knowledge (e.g. Knorr-Cetina & Amann, 1990). However, the question remains: how do learners build knowledge structures that may enable them to notice and recall various domain specific patterns? Specifically, little is known about the many micro level observations that can support learning to see complicated domain specific patterns, especially in content domains where complex observation is important, such as real-world geologic settings. This analysis employs Knowledge in Pieces (KiP) to examine the perceptual and inferential ways people read out characteristic information from the world (diSessa & Sherin, 1998).

Data and methods

Data were collected from a summer geology class for in-service science teachers that included a field-based learning experience. Using a scaffolded scientific inquiry, the participants observed rock formations and used their observations to construct an understanding of the historical geological record. The participants were 19 middle and high school science teachers in a master's program where they would earn an MS degree in physics with a focus on teaching, and this geology class was a program requirement. Participants had a range of expertise in geology, some teachers had their undergraduate degrees in Earth Science, while others were new to geology.

Data consists of audio recordings of participants' conversations while in the field along with field notes and photographs taken by the researchers. Using qualitative techniques, the audio conversations were sorted based on the degree of confidence with which teachers made observations and drew inferences, and the learning apparent in the observations. From this corpus we identified cases as representing well developed knowledge systems, moderately well-developed knowledge systems, and least well-developed knowledge systems.

Analysis: A continuum of knowledge structures related to observation

Here we illustrate the continuum of knowledge structures related to observational knowledge with three cases. We describe the structure of each knowledge system with respect to fragmentation, and quality and quantity of extractions and inferences.

In the first case, several teachers used a well-developed knowledge system to instantaneously recognize fossilized *ripple marks,* that were the result of water flowing over sediment. One teacher explicitly described what she saw (extraction) and how the ripple marks would have been created (inference) ("Yeah, the ripple marks are preserved// I know, I mean, metamorphic) and then added more specific details ("We think it's just plain sandstone that has been uplifted."). Other teachers agreed with similar extractions ("It's rippley like you are looking right at the bottom, right down from two feet of water at a beach.") They instantaneously extracted information about the existence of ripple marks, and they inferred correct and incorrect information about the formation being caused by uplifted sandstone and not metamorphic processes. Here there are relatively few extractions and inferences as the participants easily hone in on the relevant information, which suggests a more coherent and well-developed knowledge system in regards to these specific extractions and inferences.

The second case illustrates asymmetric expertise as a teacher (B) extracted a great deal of information, and struggled with two reasonable inferences, while the geology course instructor used a well-developed knowledge system to make a determination. The conversation centers on whether a crisscrossing pattern represents fossilized mud cracks or fossilized animal trails (a trace fossil). B extracted information about the color and crisscrossing pattern in the rock ("some greys, like this here is grey and that is brown. The brown is obviously more, look at that, we've got a, more like a fossil of a mud flat. Kind of like that those things down there [referring to dried mud that is underfoot]") that were identified as features of mud cracks ("See how you have mud that cracks like that?"). Later B described the two options he had inferred ("either that is some sort of biological something going on, biological, like something making tunnels. Or this is a mud crack. A fossilized mud crack.") B carefully compared the observed patterns, noting that the mud crack was angular with chasms between the cracks ("it looks more angular, I guess. But you have like these little chasms in there") and had sharp curves in both rocks ("Curve, cut. We've got a curve, we've got a sharp cut.") But he also offered evidence for the fossilized wormhole hypothesis ("What makes me wonder if it's a wormhole though, is the depth at which that thing is cut.") To help decide among the possibilities, B calls the geology course instructor (H) over and she explains that the pattern on the rock was formed by an animal trail ("Just because it's got some rounded edges to it. Actually, I can see some tracks. That looks like a trace fossil to me// Some kind of critter.") The course instructor's coherent knowledge system used a limited number of extractions and inferences and she was able to quickly recognize it as a trace fossil. Comparably, B's knowledge structure contains more extractions as he over-generates possibly relevant observations in an attempt to hone in on the relevant information for determining the rock's formation.

The third case shows contrasting knowledge systems among two teachers working to determine rock composition. While looking at a shale formation, one teacher (A) quickly identifies the rock as shale and then works to help the other (N) arrive at the same determination. The first teacher (A) quickly identifies the rock as shale based on his extractions ("This is definitely too fine grain to be sand. I notice there's a pattern to how it's breaking.") For that teacher, intermediating inferences led to his determination ("it's what we call the fissile layers.") But, N connects the pattern of breaks in the rocks to clay, not shale ("it's all breaking the same way like those clay") and he does not mention grain size, which comparably for A is a key extraction. Furthermore, N mentioned that the rock "pulls apart real easy" as justification the rock being shale, but A attributes this flakiness to weathering, which is not a characteristic to identify the rock as shale. Here we see that A's knowledge structure has tight connections between extractions and inferences, which suggests that it is well-developed. In contrast, N's knowledge structure does not identify relevant inferences and has some unnecessary extractions, which suggests it is less coherent.

Discussion and conclusion

The results show a continuum from less well-developed knowledge systems to more developed knowledge systems in regards to the coherence of the localized knowledge system, and quantity and relevance of extractions. The ripple marks case involved a coherent knowledge structure and contains few extractions. Similarly, the instructor (H) in case 2 and the teacher, A, in case 3 both used knowledge structures that are more coherent, with few, but highly relevant extractions. Interestingly, across the continuum, the number of extractions follows a nonlinear path with few exhibited by either those with the least well-developed knowledge systems (e.g., N in Case 3) and the most well-developed knowledge systems, and those in the middle with moderately well-structured knowledge systems (e.g. B in case 2) generating the largest quantities of extractions. Perhaps participant's like B in case 2 have enough familiarity with the topic to be struggling to generate and connect pieces of information in meaningful ways, whereas less-experienced participants do not have the experience to identify potentially relevant extractions and inferences and more experienced participants easily identify relevant extractions and inferences. These results build on prior work (e.g. Eberbach & Crowley) to illustrate a nuanced relationship between observation and disciplinary knowledge. Supporting movement along the continuum may involve scaffolds to support participants in identifying relevant extractions and inferences when making micro-level observations.

References

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