# Elements of expertise in the use of analogies in a 3rd-grade science discussion

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Expertise in science involves the generation and use of analogies. How and when students might develop this aspect of expertise has implications for understanding how instruction might facilitate that development. We're at the beginning stages of trying to understand analogies as students use them in science classrooms. In a study of K-8 inquiry in physical science, we have seen several cases of spontaneous analogy generation at different levels of sophistication. In the case presented here, a 3rd-grader generates a particularly well-developed analogy and modifies it to reconcile his classmates' counter-arguments, allowing us to identify in these 3rd-graders specific elements of expertise in analogy use.

Generating and using analogies are things that scientists do regularly to expand and communicate their knowledge [1]. Science teachers have also been known to use analogies spontaneously in the course of their practice [2]. Therefore, identifying and encouraging elements of this expertise in students should be an important goal for science instruction.

The use of analogies in instruction, whether initiated by the text, by the teacher, or by the students themselves, has been shown to improve student conceptual learning in a variety of fields [3]. Accordingly, much research in cognitive psychology has focused on determining the reasons analogy use can be so helpful [4]. More relevant to this study, however, is the fact that several different elements of expertise in generating and using analogies have been identified, or at least suggested, by education and psychology researchers.

The most obvious element is simply that of *generating analogies* in the course of learning. Clement [5][6][7] showed that many undergraduates and experts spontaneously generate analogies when solving physics problems. Analogies are generally conceived as consisting of a *target* case (about which new knowledge is desired), a *base* case (which is generally already understood to some extent), and a *relation* that maps elements from one case to the other. Else and Clement [8] have suggested that establishing familiarity with the base and carefully mapping the base to the target are important parts of analogy generation.

*Validating the analogy* is another important part of what experts do [7]. Several have suggested that students should be able to *criticize* a particular analogy and determine its limitations by looking for similarities and differences between target and base [7][9][10]. It's also important to be able to *refine* an analogy in response to this criticism, something that has been seen in undergraduates in physics [6][9] and psychology [10].

An analogy may also be used to *make new inferences* about the target [11] or construct more abstract knowledge or general principles [6][11]. Also, as mentioned above, analogies may be used to communicate knowledge to others.

While many of these aspects of analogy use have been documented in experts and older students, research has not focused on how young children use analogies in science, and if they use analogies in ways similar to experts or in different ways. In this paper we provide a detailed example of how one 3rd-grade student, Skander, generates and uses an analogy when engaging in inquiry in physical science with his classmates, and how his classmates respond to it. By looking closely at this episode, we have begun to identify some of the elements of expertise in analogy use that can be seen among young children and therefore may be developed and encouraged by instruction.

**The class**

As part of a project to produce case studies of elementary student science inquiry, Patricia Roy's 3rd-grade class was occasionally videotaped. On this particular day, 26 students were present for a 30-minute inquiry lesson which consisted entirely of a loosely guided student discussion on a single topic. The class had just finished a unit on natural disasters, and so Ms. Roy chose to start with the question, "What causes earthquakes?" (The unit had covered volcanoes, but not earthquakes.) Ms. Roy's role in the discussion was to ask clarifying questions and to call on students, but not to provide "the answer" or to pass judgment on the students' explanations.

**The discussion**

In the first 15-20 minutes of the discussion, several students proposed several different ideas for what might cause earthquakes, from "scientists digging in the earth trying to find dinosaur bones" to "it's broken ground already and it just starts to crack again." Others mentioned dry land, the heat of the earth's core, crashing spaceships, and ground that's too thin or too old as possible causes. Also mentioned are the ideas that the earth's rotation causes it to shake or that the rain makes the ground "soft and crumbly."

During this initial period, Skander participates along with the others. He agrees with other students' ideas about the "heat from dry land" as somehow causing earthquakes. He also puts forth his own general idea that something must "crack the ground" all the way down to the earth's "lava center" for an earthquake to happen. He suggests that phenomena such as meteors, tornadoes, or a ficticious "giant drill" could start the process by cracking the ground, but doesn't seem to think it necessary to come up with a single explanation.

This is borne out later when Skander articulates another possible explanation, one that is consistent with his general idea that something must "crack the earth" (although in this case the earth is cracked from below). He suggests that a rock falls into the lava that lies underneath the earth's surface, causing the lava to rise:

*You know if the ground is closed and there's lava, like, a giant rock, er a giant rock might fall into the lava and which would cause the lava to go up because it's pressing it to go up. ... if it goes into the lava it cause it to go up and then the ground starts shaking to um open.*

Since the lava "needs space to go up," Skander explains, it presses on the ground from below, causing the ground to shake and crack.

In keeping with the style of the conversation so far, the students listen to Skander, but don't actively address his explanation. Then Skander repeats his idea, this time explaining it in terms of an analogy:

*You know how if you fill your water up and you put like too many ice cubes in it, it can flood? That's what I mean. ... a rock could go in, and pretend like, pretend the lava is water and the giant rock is a cube. It goes up and since it's blocked, the ground has to shake which causes it to crack open so it it'll actually like go up farther. So it's like you're actually flooding the cup of the water.*

Skander is making an analogy between how ice cubes make the water level rise and how rocks can make the lava level rise.

Skander's contribution shows several elements of expert-like thinking. First of all, he generates his analogy spontaneously. His reason for generating and using it appears to be to help his classmates understand his original idea about rocks in lava, although it's also possible it helps him develop his own understanding of the situation. Second and more specifically, he establishes familiarity with the base by inviting the class to consider a familiar situation, using phrases like "You know…?" and "pretend." Third, he carefully maps elements of the base to the target. Fourth, he appears to seek consistency in his application of the analogy by going from base to target and back to base. Fifth, he seems to do all this unselfconsciously, not perceptibly worrying that using an analogy is taboo or irrelevant.

The rest of the conversation shows that the other students don't seem to have a problem with the fact that he uses an analogy either. On the contrary, as soon as Skander presents his analogy, the focus of the class discussion shifts. Now students are actively considering Skander's original explanation about rocks in lava, although in different ways. Almost immediately, Hugo and Ben disagree with Skander and present a counter-argument. Hugo states it first, "… if the um a giant rock goes into the lava, that will make it melt." To elaborate on the effect of lava on a rock, Hugo spontaneously generates an analogy of his own, "It's like acid," although he uses it differently than Skander uses his - to illustrate a single point rather than an entire explanatory mechanism. It's not evident from their comments whether Hugo and Ben are criticizing Skander's explanation alone, or if they take issue with his choice of icewater as an appropriate analogy.

Skander responds quickly to this counter-argument. At first, he prefaces his response with "I don't agree with Ben," but then changes to "I kinda agree with Hugo and Ben, but I also agree with myself," an indication that he has reconciled their argument with his. He acheives this reconciliation by revising his original explanation only slightly to account for the fact that the rock (as he freely admits) does indeed melt:

*…the rock would actually go into the lava but melt, but cause more lava, because when it melts, it's like, it's like you're adding more lava and it'll cause, it still crack to make an earthquake.*

Even though he doesn't mention ice or water here, it's possible that Skander's analogy helped him come up with this way to resolve Hugo and Ben's counter-argument, by cueing thoughts of ice melting and becoming liquid water. If so, it is an example of applying an existing analogy to make new inferences about the target situation. If not, it still represents an important resource for scientific reasoning: reconciling inconsistencies by refining an explanation.

Not only does Skander's revised explanation meet with agreement from at least two students, but it also prompts one of them to come back to the icewater analogy. Andrew says:

*I agree with Skander too because if you put a ice cube in* [inaudible] *and wait, in some water and wait for a long time, it melts and makes more water.*

This is the first direct indication that someone other than Skander is using the analogy, since Andrew is the first to mention it explicitly. His comment is sophisticated because he is *extending* Skander's original analogy, in order to reconcile further the counter-argument put forth by Hugo and Ben.

After Skander explains his idea once more in terms of his icewater analogy, Alex presents another counter-argument:

*I disagree with Skander because water and ice cube is practically the same. An ice cube is just frozen water, and rock is different than lava, 'cause lava isn't, isn't, isn't made, doesn't become a rock when it's frozen.*

This counter-argument reveals two things about Alex's thinking. The fact that he is criticizing a peer's analogy at all is one sign of sophistication. Another is the form the criticism takes: identifying a difference between the target (rock in lava) and base (ice in water). Although he may be expecting too exact a relation (an example of overmapping [8]), Alex seems to believe that this difference is a serious limitation of the analogy. What remains unclear, however, is what exactly this limitation means for him. Is he simply rejecting Skander's choice of icewater as an appropriate analogy, or does he disagree with Skander's entire explanation of rising lava? Is he thinking that an inappropriate analogy *automatically* makes the explanation wrong?

Later, Skander may be attempting to reconcile Alex's counter-argument when he says that "the lava would still go up" because the rock is "taking space," but he isn't very clear and no one follows up with it.

The last several minutes of the conversation shows a different kind of response from several students, one in which they conflate the ice/water analogy with the rock/lava explanation. Jovan begins to talk about what would happen to an *ice cube* if *it* were placed in lava, and several others follow suit. Although the students may not have done it deliberately, they seem to have constructed a *bridging analogy* [12], an intermediate situation between the base and target that can help transfer knowledge from one to the other. Alternatively, the analogy of ice in lava could simply be closer to the target situation and therefore easier to apply for these students. At the least, Skander sees this intermediate situation as helping his case: "if you put a giant ice cube in as a giant rock, you, the um, the ice would actually melt which would cause a flood." The class is still talking about putting ice in lava when time runs out and the lesson ends.

## Conclusion

This case study shows that young children can exhibit expert-like thinking with regard to the use of analogies in learning science. Skander shows perhaps the most sophistication, but others in the class also show important elements of expertise.

What can we make of this? Were Skander and the other children taught how to use analogies in science? Probably not. Are the children featured here somehow gifted? No. These are ordinary children with varied performance in different subjects. In fact, in our project we have seen many examples of analogy use in other science classrooms, such as 1st grader Kaan explaining how if you place books on curved surfaces, they will slide off, "sort of like a roller coaster," or 5th grader Miranda using her experience swinging a toy cat in a basket overhead to figure out what happens to the water in an inverted falling cup. Would we be surprised to hear *any* child using analogies in other contexts, such as in telling a story? Again, probably not. Yet they may not use these resources in science class unless the environment allows for it. They may not continue to develop their sophistication unless it is recognized and encouraged by a teacher capable of truly listening, not just to *what* the students are learning, but also to *how* they are going about the learning process.

If educators are to be successful in helping students develop expert-like thinking skills, it's crucial that we are aware of what resources for thinking students bring to the table. This case study shows that even young children already have many of the elements of expert thinking.

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