7: Yeah, it is losing heat. That is what is making it colder.

In this discussion, the teachers begin with a description of "icy-coldness" moving into the hotter object (line 1). This suggests both that coldness is a kind of energy and it flows from cold to hot. Some teachers object, raising questions about which process needs to be explained (line 2 and 3). In lines 4 and 5, the discussion is of heat moving from the soda can to the snow. But, a teacher (in line 6, same as in line 1), raises the issue of the soda can getting colder - it seems that the issue is not just how the heat flows (making the snow warmer) but that the coldness of the can needs to be accounted for. The teacher takes the idea of heat going out and accounts for the change in temperature, and in line 7, this idea is affirmed.

We make three points about this interaction. First, we see teachers thinking about the direction of energy transfer, from the soda can to the snow in the form of thermal energy transfer or heat loss. They considered implications in terms of changes to the temperatures of the objects in the system. The snow would melt, and the can would get colder, both due to the single effect of energy transfer.

Second, and more problematic, we see teachers using terms associated with heat to describe the temperature of the object ("hotter temperatures," line 1), the movement of energy ("heat… moving," line 5), and some combination of the two ("heat loss," line 3, "losing heat," line 7). This result, and the associated confusion between heat and temperature, is well-known in the research literature.

Third, we see evidence of the same lack of clarity about terms associated with cold. In line 1, the suggestion is that icy-coldness moves into the hotter temperature object, as if it were a kind of energy. (One can imagine not a T, like in the right picture in Figure 2, but a C, for coldness, that travels into the metal rod.) In lines 6 and 7, "colder" is used to describe the temperature of the object. We note the shift between lines 1 and 6, as the teacher first uses "coldness" (as a kind of energy) to account for the soda can getting colder, but then shifts to having "heat going out" to account for the temperature being colder. This reconciles the heat and coldness models in a way that many students have not (as discussed in section IV).

In considering the use of hot, cold, heat, thermal energy, and coldness, we conclude that the language used in the Sue Question and the Soda Bucket Question (Figure 1) is grossly inconsistent. We note that we have since changed the language of the Sue Question to be consistent with the Soda Bucket Question (for example, not using heat but using thermal energy instead), but that preliminary results show no change in student responses before instruction. The issue of coldness still dominates, suggesting that understanding how objects get colder remains difficult and was not simply an artifact of a badly phrased question.

VI. CONCLUSIONS

In everyday life we use language that suggests movement of coldness, such as the idea of letting "coldness" come into a house in the winter ("Close the door, you're letting the cold in!"). Students bring these kinds of ideas into the classroom. When it comes to gaining a solid conceptual understanding of transfer, transformation, and conservation of energy in middle school classrooms, considering coldness as a form of energy may be problematic. Our data show that students' thinking about coldness persists after instruction and that many students consider that both thermal energy and coldness are transferred between objects.

This problem has been identified in the literature [11] and was identified by MainePSP teachers as a problem, as well. During teachers' discussions, the challenges presented by everyday language were evident. In teachers' discussions, multiple ideas about thermal energy, heat (as thermal energy), hotness (as temperature), and coldness (as temperature or as an alternative to thermal energy) were discussed and, at times, had to be resolved. There is a lack of current literature regarding instructional strategies to address the topic of "coldness" as a kind of energy. Our study shows that we still need to find effective strategies to address student thinking about coldness.

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