Asking for too much too early? Promoting mechanistic reasoning in early childhood science and mathematics education

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Abstract: Following research attention to children’s use and understanding of causation, in this paper we contend that young children as early as kindergarten are able to engage in an effort to develop understanding about the causal mechanism underlying or explaining physical and mathematical phenomena. We draw on two examples from early childhood education settings to suggest that children are able to use (novice) abilities of mechanistic reasoning both in early science and mathematics education. We discuss implications for the role of the teacher and activity design.

Theoretical framework
During the second half of the twentieth century, “good science teaching and learning” has become increasingly associated with inquiry (Anderson, 2002). Working from a variety of perspectives and intellectual traditions, research regarding children’s abilities for scientific inquiry shows a general consensus with respect to the sorts of things we should value and try to promote in children’s inquiry. That consensus, however, does not extend to the definition of what scientific inquiry looks like in the science classroom. One area of research is drawing particular attention to the scientific discourse that involves causal mechanisms (Russ, Scherr, Hammer and Mikeska, 2008), following a number of studies that partly focused on children’s use of causation in science. This suggests that “assessing when and how children seek causal mechanisms in their understanding should be part of assessing their reasoning as inquiry” (Russ, et al., 2008, p.1). Using a framework derived from the philosophy of science, Russ et al. (2008) developed a coding scheme of 7 major components of mechanistic reasoning that can be used to identify and assess children’s use of such reasoning. Those components include (i) descriptions of the target phenomenon (what we see happening), (ii) identification of the set-up conditions that are necessary for the phenomenon to happen, (iii) identification of entities (conceptual or real objects) that play a particular role in the phenomenon, (iv) identification of the entities’ activities that cause changes in the surrounding entities, (v) the entities’ properties, (vi) the entity organization (how entities are located, structured or oriented within the phenomenon), and (vii) chaining; that is using knowledge about causal structure to make claims about what has happened prior to a phenomenon and what will happen.

In this paper, we analyze a number of videotaped incidences from authentic early childhood education settings. We aim to provide evidence that searching for opportunities to promote or to design for, mechanistic reasoning is a tangible goal for early childhood education. Our stance is that children come to class already having abilities to engage in mechanistic reasoning. Teachers need to help them refine these abilities and more importantly, they need to help children develop reliable access to these abilities, for their use in the appropriate context and time.

Methodology
This interpretive case study illustrates young children’s nascent abilities for mechanistic reasoning. Data originate from two activity sequences carried out with children (ages range from 3,5-5 years old). The activity sequences were implemented by two different senior student-teachers, one in science and the other in mathematics. Prior to these activity sequences, the children had no previous formal instruction of, or about mechanistic reasoning. From the videotapes, we identified episodes of student inquiry related to mechanistic reasoning in both activity sequences, and coded the transcripts using Russ et al’s (2008) coding scheme to determine which aspects of mechanistic reasoning were used by the children. In doing this we sought to describe the variability in children’s mechanistic reasoning, as well as the contextual possibilities that might have led to different uses of mechanistic reasoning in these pre-school science and mathematics activities. Below, we briefly present two short analyzed excerpts that are representative of the findings in support of our claims.

Findings
The science activity sequence was carried out in a class of 3,5 and 4 year olds. The topic was floating-sinking, and children’s goal was to help an ant to build a boat to cross a river. From the outset, children realized that the ant’s suggested materials could not be used for the boat, as they sank. Thus, children decided that they needed to investigate which alternative materials might float and subsequently be used for building a boat. Among the materials the teacher had prepared, were two identical pieces of aluminum foil, one left as a thin sheet and the other crumpled into a ball. During the experiment, all the student groups discovered that the two pieces of aluminum foil behaved differently in water – the one crushed into a ball sank, while the sheet floated. After the
groups presented their findings to the whole class, the teacher wanted to draw children’s attention to the different behavior of the two foil objects. During that conversation, the types of student responses varied. For some time, children focused on the differences in the two objects’ characteristics – that the foil that sinks is “folded”, “small”, “like a pie” etc. Then, a child started a very different line of thought, in an effort to explain how the different behavior of this aluminum foil piece is caused. His contribution approaches a representation of the mechanism that causes the phenomenon. Having already described the target phenomenon and its set-up conditions, the child identified a possible physical entity (force) that may account for how the phenomenon took place, indicating that it was this force that may have made the difference and resulted in the foil floating.

The mathematics activity was carried out in a class of 4 and 5 year olds. The children were given the following problem: “How many different shapes can you make by putting together two congruent scalene, right-angled triangles so that one pair of congruent sides is always shared?” After the children worked in pairs they concluded that they had found 5 different solutions to the problem. Then, they reproduced the 5 solutions by using sets of triangles which were marked using blue, red and green to show each set of congruent sides. At this point the children noticed that there were two different solutions with the blue sides joined. The teacher asked the children how come there were two solutions with the same sides joined. One child gestured using her hands that if you flip over one of the triangles you get a different solution. After discussing the 5 solutions the children concluded that since there were two solutions for the blue sides, two for the red sides but only one for the green there was probably one solution missing. Based on Russ et al’s (2008) coding scheme we can identify the components of mechanistic reasoning. The children described what they saw happening – there are two solutions for the same set of congruent sides. In order to do that, the children identified the conditions and described the entities which played an important role in the phenomenon – this phenomenon arose while trying to construct shapes by putting together two congruent scalene triangles so that one pair of congruent sides is completely shared. Finally, the children became involved in a chaining procedure where they tried to interpret their observation which allowed them to formulate a hypothesis in relation to the missing solutions to the original problem, namely that there are two solutions for each set of congruent sides which result when flipping over one of the two triangles, thus the total number of solutions to the problem must be 6.

Conclusions and Implications
Although we do not claim that our findings cover the complete spectrum of mechanistic reasoning in early childhood education, findings reveal insights with respect to the challenge of defining how mechanistic reasoning might look like in the classroom and what teachers should expect to see, regarding what “productive” inquiry entails in young children. Overall, our findings provide evidence that young children come to class already having abilities to engage in mechanistic reasoning, and we describe the contexts in which mechanistic reasoning might take place. In this context, our findings also highlight some ways in which the teacher can grasp children’s spontaneous reasoning, be aware of the manner in which an activity might develop so as to engage children in mechanistic reasoning and design activities to create opportunities for this. Lastly, we would like to underline that the children in the videotaped incidences described exhibited the ability for mechanistic reasoning with no prior formal instruction in this type of sophisticated thinking. We do not suggest that young children are experts in scientific inquiry, but rather that they have the beginnings of abilities for mechanistic reasoning. In this, we feel that the literature over-emphasizes the need to “teach” students how to construct, evaluate and respond to causal mechanisms, analogies and arguments. Rather, our findings question whether we should re-focus teaching efforts towards identifying the beginnings of young children’s abilities for mechanistic reasoning, and describing the learning conditions under which mechanistic reasoning might take place.

References

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