Mechanism and Problem-Solving: What do you want to know?

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Abstract

From at least as early as 30 months of age, children show an interest in and preference for causal mechanistic explanations. While this preference is supported by several studies of children in both home and laboratory settings, not much is known about the strength of the preference, or whether it is flexible based on the context in which the preference is being considered. The present study examines this question by designing two contexts: (1) fixing a mechanical device that is broken or healing a living entity that is sick, in which information on an artifact's causal mechanism, or how its parts causally interact to produce its function, seems intuitively helpful and (2) selling a device or artifact, in which other information, in this case non-mechanistic marketing information, might be more useful. The first part of the study tested adult participants on Amazon Mechanical Turk (mTurk), finding that adults prefer having mechanistic information when fixing or healing something, and non-mechanistic marketing information when selling something. The second part of the study worked with 5-10 years old children, finding that while children similarly prefer having mechanistic information when fixing or healing something, they are show a trend for preferring mechanistic information when selling something. These results confirm previous research that children have a preference for learning about causal mechanism, and furthermore, show that because this preference is so strong and because children are relatively immune to the demands of different contexts, preference for mechanism overrides context.

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1. Introduction

Anyone who has spent time with children knows that they are curious: infants learning to crawl and walk use their newfound mobility to scamper about, touching everything in arm's reach; elementary school aged children ask endless questions, to the delight and occasional annoyance of their teachers. From a young age, children gather information about their surroundings to understand the world around them, both by using their own physical senses of sight, touch, taste, and smell, and by asking questions of others. However, beyond mere curiosity, some studies suggest that children have a particular desire to learn about causal mechanisms, systems of parts that causally interact to produce predictable outcomes, in order to have explanations for how artifacts and phenomena in the world operate. This seemingly strong and early emerging preference for causal mechanism has broad implications for STEM education and how to best approach teaching children concepts and processes in their STEM courses. The present study explores the strength of this preference in children, and whether it varies based on context.

1.1 Casual Mechanism

Causal mechanisms are systems of "internal" parts or variables that predictably and causally interact to produce "external" behaviors or outcomes (Glennan, 1996; Machamer, Darden, & Craver, 2000). Causal mechanisms can be used to describe the internal systems of entities (e.g. how the parts of a vacuum cleaner interact so it is able to suck up dust; how the factors necessary to produce a tornado interact to cause one) or broader systems (e.g. the stock market; perceptual mechanisms) (Glennan, 1996). Understanding mechanism is broader than just grasping causal relations, because mechanistic reasoning requires a more systematic grasp of several causal relations responsible for a larger scale phenomenon, given that underlying two causally linked events, there is a broader system of connected parts that interact to cause an outcome (Ahn & Kalish, 2000). Mechanistic understanding is also typically construed as knowing the relevant causal details at a given level of explanation and does not require exhaustive reductionist understanding (e.g., understanding the detailed fluid dynamics of airflow in a vacuum cleaner). Additionally, because causal relationships are embedded into different levels of causal systems – if an outcome was brought about by a particular cause, that cause can likely be explained by a preceding cause, and so forth – knowing about one causal mechanism can give us more information about the entire system (Johnson & Keil, 2014).

Understanding mechanisms is crucial to human cognition because they underlie the causal relationships that explain the events and phenomena in the world around us. This can help us to predict outcomes, make inferences, and grasp broader systems. In short, understanding mechanisms helps us to "infer the unknown from the known" (Johnson & Ahn, in press).

1.2 Children's Understanding of Causality and Mechanism

Piaget, who conducted some of the earliest work on children's perceptions of causality, postulated that children only understand causality at the age of seven or eight, labeling infants and preschoolers as "pre-causal" (Piaget, 1929, 1930). However, more recent studies have shown that this understanding emerges much earlier. Three-, four-, and five-year-olds who were shown a sequence of causally related mechanical events identified the first event as the cause (Bullock & Gelman, 1979). Gopnik et al. demonstrated that two-, three-, and four-year-old children were able to make accurate causal judgments based on variation and covariation; the same study was replicated with 19-month-old infants (Gopnik, Sobel, Schulz, & Glymour, 2001; Sobel & Kirkham, 2006). Other studies suggest that infants, even those as young as six-months-old, show some sensitivity to causality, and that they can learn about causal principles through mere observation (Leslie & Keeble, 1987; Oakes & Cohen, 1990; Waismeyer, Meltzoff, & Gopnik, 2015).

The questions that children ask give us some more insight into the depth of their curiosity, not just regarding causal relations, but a desire to learn specifically about mechanistic explanations. A study that asked parents to keep track of the questions their children spontaneously asked them demonstrated that children as young as 30-months-old, asked adults "why" or "how" questions (Callanan & Oakes, 1992). The questions were not merely series of repeated "Why?"s, but more complex and thoughtful: "Mom, why do you have green eyes and I have blue eyes?", and "How do electric wheelchairs work?" While simply asking "Why?" to parents might reflect a child's desire to engage them or to get attention, the kinds of questions that children asked showed that they were seeking information in the form of mechanism-rich responses. Unsatisfactory answers prompted further questions until children were content with the information that they receive.

When children receive explanations to their questions, they are more likely to agree or ask follow-up questions; whereas, when they receive non-explanatory responses, they are more likely to re-ask the original question or to offer their own ideas of explanations (Chouinard, Harris, & Maratsos, 2007; Frazier, Gelman, & Wellman, 2009). Furthermore, it is not merely the structure of a mechanistic explanation that children prefer, for they show a robust preference for noncircular over circular explanations, even when both explanations are structured in a way that mechanistic explanations typically are: 'result' "because" 'explanation' (Corriveau & Kurkul, 2014). These results have been replicated in both natural (home) and laboratory environments. However, one limitation of these studies is that they have focused on questions spontaneously initiated by children. Very few studies have presented different forms of explanations to children and asked for their preferences, as we do in the present study.

1.3 Effects of Context

Studying the effect of context on children's preferences for causal mechanism is related to the broader body of research examining the effects of context on children's cognition. The broader contexts, or more generally, environments, in which children are raised and learn about the world inevitably affect their problem solving and decision-making. But even in laboratory settings, when local context is varied, children's decisions are affected. For example, Gutheil, Vera, and Keil (1998) demonstrated that presenting information in a biological context (e.g. "This person eats because he needs food to grow…") vs. a psychological context (e.g. "This person eats because he loves to be at meals with his family…") caused 4-year-old children to generalize the biological qualities to other animals, such dogs and fish, at higher rates than they did the psychological ones (Gutheil, Vera, & Keil, 1998). Another study showed that presenting information about novel entities in a scientific context caused three- to five-year-olds to believe the entities were real more often than when the same entities were presented in a fantastical context (Woolley & Van Reet, 2006). These experiments demonstrated that young children form different beliefs and inferences about the same information when it is presented in different contexts. However, it is still unknown whether children are sensitive to the contextual demands of different tasks, or whether they are largely immune to these.

1.4 Present Study

The present study aims to test the strength of children's preference for mechanistic information by seeing if this preference holds across various contexts, even ones in which other non-causal, non-mechanistic information might be more useful than mechanistic information. We were interested in if children believe that while understanding mechanism is generally useful, understanding other qualities about artifacts might be more useful in particular contexts, or if their preference for mechanism is so strong that it holds regardless of the context. The study was first performed with adults on Amazon Mechanical Turk (mTurk), and then run with 5- to 10-year-old students.

To test the preference for mechanistic information across contexts, we designed two contexts: (1) fixing a broken mechanical object/healing a sick biological entity and (2) selling the artifact. These two particular contexts were chosen because we wanted to have one context (fixing/healing) in which mechanistic knowledge would be more useful for achieving a goal than non-mechanistic knowledge, and another (selling) in which mechanistic knowledge might be less useful than the non-mechanistic knowledge. More specifically, the non-mechanistic information that was presented was relevant to marketing, and that would be useful when trying to sell something. We used a between-subjects design, with participants being randomly assigned to the fixing/healing condition or the selling condition. Participants were told four stories about four different mechanical objects and biological entities that they needed to either fix and heal, or sell. For each artifact, they then had to make a choice between two individuals to whom they could talk, one who had information on the artifact's mechanism, and the other who had information that was non-mechanistic, but relevant to marketing.

We predicted that adults would strongly prefer the mechanistic information for the fixing condition and strongly prefer the non-mechanistic marketing information for the selling condition, because they would be able to take the context into account, and choose accordingly what information would be more helpful. By contrast, we predicted that children would strongly prefer the mechanistic information for the fixing condition and weakly prefer the non-mechanistic marketing information for the selling condition, because their strong interest in mechanism would override any sensitivity that they had to context. We expected that the older group of children, 8-10 year-olds, would be more able to consider context than the younger group, 5-7-year-olds. Thus, the older children would more strongly prefer having marketing information to sell the artifacts when compared to the younger children, but still not as strongly as adults would.

This study is part of a group of studies funded by a National Science Foundation grant. The studies are researching children's apparent interest in and preference for mechanism, and how that might affect the pedagogy of science and technology education in schools. The broader end goal of these studies is to help educators to better shape their curricula and teaching styles to most effectively promote science literacy. There are implications for how STEM is taught in schools if indeed children have a general preference for mechanistic explanations and if this preference is context-dependent. The results of these studies may suggest that teaching children in styles that are mechanism-based can mediate a way of understanding that helps them to better process and remember information and concepts, by using the way that they naturally learn best.

2. Experiment 1: Adults

2.1 Participants

One hundred and fifteen adults (M_{age} = 34.4 years; 49 females) were recruited through the Amazon Mechanical Turk (mTurk) marketplace and participated in exchange for monetary compensation. An additional thirty-one participants were excluded either for failing to complete the entire survey (twenty-six participants) or for having a response time of zero seconds on any of the questions (five participants).

2.2 Design

The experiment involves two conditions: fixing/healing and selling. We wanted to test whether participants' preference for mechanistic information would change based on the context. We did so by designing one context (fixing/healing) in which mechanistic information seems obviously useful in achieving the stated aim, and another context (selling) in which non-mechanistic information might be more useful than mechanistic information. More specifically, because we chose the context of selling, we designed the non-mechanistic information to be marketing information that would presumably help an individual to better market and sell each artifact. For the fixing/healing context, in which participants needed to fix a broken device or heal a sick biological entity, it seems preferable to have mechanistic information, because knowing how a certain object works will be helpful in restoring a broken or sick artifact to its original state of functioning. For the selling context, non-mechanistic marketing information would most likely be more helpful because it would help someone when marketing the item to know about its different models, features, or colors and sizes, rather than its mechanism.

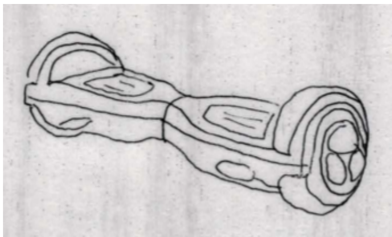
For the four artifacts, we chose to include both mechanical and biological artifacts because while both types have mechanisms, they are expressed in slightly different ways (e.g. the mechanism of a mechanical device explains its function or purpose, while the mechanism of a biological entity might explain how it eats or moves). Mechanical devices as a whole also tend to have salient purposes while living entities, less so. Moreover, when considering running this study with children, studies have shown that children can discern that the causal mechanisms of biological entities operate differently from those of psychological and physical processes (Erickson, Keil, & Lockhart, 2010; Wellman & Gelman, 1998). By testing both mechanical and biological artifacts, we will be able to see if conceptualizing their mechanisms differently causes children, as well as adults, to also differentially prefer learning about their mechanisms.

2.3 Materials and Procedures

In both the fixing/healing and the selling conditions, participants read four stories about four different mechanical devices and biological entities: hoverboards, refrigerators, Venus flytraps and goldfish. They were shown black and white sketches of each artifact. They then had to make a choice between two individuals to whom they could talk to learn more, one of whom had information on the artifact's mechanism, and the other who had information that was non-mechanistic, but relevant to marketing that artifact. All of the information provided was scientifically accurate, and for each stimulus, the two options of information were roughly matched for the number of words and word complexity. Both individuals also offered three pieces of information. Pictures of the individuals were shown, with the two individuals in each pair matched for attractiveness and affect.

For example, participants might read and see:

“You are interested in fixing hoverboards. Hoverboards are self-balancing two wheeled scooters.



To help you, you can choose one of two people to talk to:

- Mr. Jones has information about the following kinds of things. He can tell you about the kinds of batteries you need to power hoverboards. He also can inform you about how the motor works that pushes the hoverboards. Finally, he can tell you about the sensors that keep the hoverboards balanced.

- Mr. Smith has information about the following kinds of things. He can tell you about the various colors that hoverboards can come be. He can also inform you about how hoverboards can vary in size and how some hoverboards can have lights. Finally, he can tell you about where it is okay to ride and use hoverboards.

If you could choose only one person to help you, which person would be the most helpful if you wanted to fix hover boards?

- Mr. Jones, who can tell you about the kinds of batteries hoverboards use, how motors work in hoverboards, and how the sensors keep them balanced.

- Mr. Smith, who can tell you about all the colors hoverboards can come in, about the different sizes of hoverboards and the kinds of lights they can have, and also where you can use them."

Participants had to choose which of the two individuals they thought would be more helpful to talk to, and were required to type out a justification for their choice. The four entities were shown in random order, and the order in which they saw the two individuals was also randomized. To conclude, participants were asked demographics questions about their age, gender, race, and educational level. Refer to *Appendix* for the full list of stimuli.

2.4 Results

Scoring. Each participant in the two conditions (fixing/healing v. selling) made four choices – two for the mechanical devices and two for the biological entities. In all cases, mechanistic choices (choosing the person who knew more about mechanism) were scored 1 and non-mechanistic choices were scored 0, resulting in a possible score of 0-1 for each item, 0-2 for each category (mechanical devices v. biological entities) and an overall score of 0-4.

Gender and order. There were no significant gender differences in preferring mechanistic information within conditions, all $t(55/57) < 1.62$, $p > .11$. Also, there was no significant effect of order of presentation (whether participants were first presented with the individual with mechanistic information or the individual with non-mechanistic information) within conditions, all $t(55/57) < 1.05$, $p > .32$.

Fix condition. Figure 1 shows the mean category scores for the fix condition (0-2) and Figure 2 shows the mean scores by item (0-1). One sample t-tests with a test value of 1 showed that for both categories of items (mechanical and biological), adult participants were more likely than chance to choose the mechanistic response, both $t(56) > 5.79$, $p < .001$. Indeed, for all individual items, participants were above chance in selecting the mechanistic response, all one sample $t(56) > 4.42$, $p < .001$, test value = 0.5. A paired sample t-test revealed that the endorsement of mechanism did not differ between the two categories (mechanical v. biological), $t(56) = 1.09$, $p = .28$. Finally, the mean total score (0-4, $M = 3.18$, $SD = 1.21$) for the fix condition was significantly above chance, $t(56) = 7.32$, $p < .001$, test value = 2.

Sell condition. Fig. 1 also shows the mean category scores for the sell condition (0-2) and Fig. 2 shows the mean scores by item (0-1). One sample t-tests with a test value of 2 revealed that for both categories, the participants were below chance in their endorsement of mechanism, both $t(58) < -3.51$, $p < .002$. A paired sample t-test showed that there was a tendency for participants to endorse mechanism more in the mechanical device condition than in the biological entity condition, $t(58) = 1.80$, $p = .08$. This is likely due to participants' responses to the hoverboard item. One sample t-tests showed that participants were below chance in selecting the mechanistic response for all items (all $t(58) < -4.30$, $p < .001$, test value = 0.5), except the hoverboard, which "hovered" at chance, $t(58) = -.648$, $p = .52$. Looking at mean total scores, participants overall were less likely than chance to select mechanistic responses in the sell condition, $t(58) = -5.16$, $p < .001$, $M = 1.19$, $SD = 1.21$, test value = 2.

Fix v. Sell Condition. Independent sample t-tests found that participants were more likely to choose the mechanistic response in the fix condition than in the sell condition for both categories (mechanical v. biological) as well as for all items within the categories, all $t(114) > 3.89$, $p < .001$.

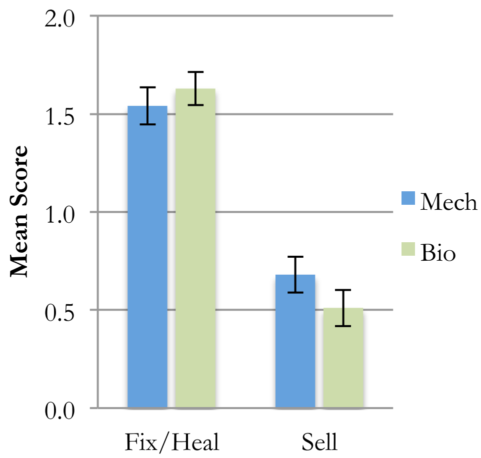


Figure 1. Adult Mean Scores by Item Category

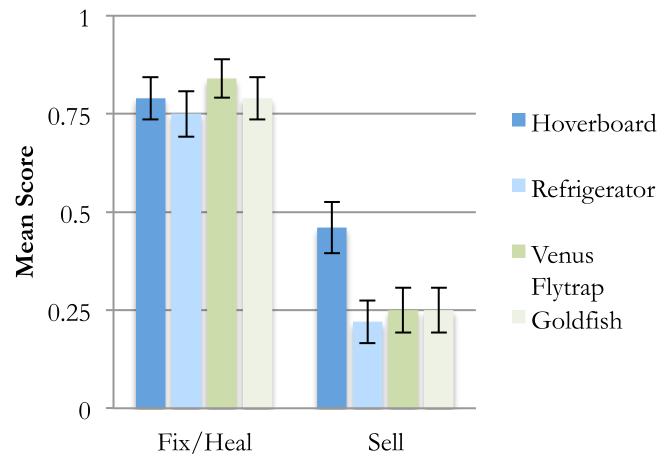


Figure 2. Adult Mean Scores by Item

2.5 Discussion

Our hypothesis for adults was confirmed: in the context of fixing/healing, adult participants significantly preferred having mechanistic information overall, as well as for all four individual items and both categories of items (mechanical and biological). In the context of selling, participants significantly preferred having non-mechanistic information overall, for both categories of items, and for all individual items except for hoverboards, for which they were at chance choosing between mechanistic and non-mechanistic information. These findings suggest that adults are sensitive to the context of a problem when choosing what information they think would be most helpful in solving that problem. Furthermore, if adults do have a baseline preference for learning about mechanism, context takes precedence over preference when they are choosing what would be the most helpful information.

The pattern for selling hoverboards stood out for being the only condition in which participants were at chance when picking between mechanistic and non-mechanistic information. This may have emerged for a few possible reasons: 1. Hoverboards might seem like an exciting artifact because they are newer and trendier. Thus, more participants might be interested in knowing how they work, and this preference might be so strong as to override the context of selling. 2. Participants might believe that prospective hoverboard buyers will ask about its mechanism, and thus, that they should know about mechanism when trying to sell hoverboards. 3. Some stories of hoverboards catching on fire have been in the news; thus participants might believe that they need to understand the hoverboard's mechanism in order to assuage prospective hoverboard buyers who might be skeptical of purchasing because of safety hazards. Based on the justifications from participants who chose the mechanistic information, it seems that the first two reasons are more probable than the third, as no one mentioned the hoverboard safety hazards. For the sake of analyses on this first set of adult data, we collapsed the data for selling hoverboards and refrigerators, but it seems as though, at least with adults, the fact that participants are choosing equally between mechanistic and marketing information in the selling hoverboards condition has more to do with the particulars of that stimulus, rather than with a broader phenomenon, given that for selling the other mechanical stimulus, refrigerators, participants preferred the non-mechanistic marketing information.

3. Experiment 2: Testing with Children

3.1 Participants

Eighty-six students in pre-kindergarten through fourth grade, aged 5- to 10-years old (M_{age} = 7; 9, 41 girls) completed the study. There were 54 5- to 7-year-olds (M_{age} = 6; 10, 27 girls) and 32 8- to 10-year olds (M_{age} = 9; 4, 14 girls). (This split between the age groups of 5-7 and 8-10 was explored because it is commonly seen in the field of developmental psychology as marking major developments in children's cognition.) Students were recruited primarily from a school in Waterbury, Connecticut, as well as from children's museums in New Haven, CT and Norwalk, CT.

3.2 Design

The same four artifacts that were used with adult participants were used with the child participants.

3.3 Materials and Procedures

A similar procedure was used with the child participants as with the adults, but the information and questions that the adults were presented on mTurk were read to the children, and they were shown the pictures of the stimuli and the individuals giving information. When the experiment was being introduced to the children, they were also shown a picture that represented the context they were assigned to. For the fixing/healing condition, they were shown a black and white sketch of a hospital, and for the selling condition, they were shown a sketch of a store. When piloting the study, we ran a few child participants without these pictures, and found that it was difficult for children to remember the goal of the experiment. Having the pictures was a helpful visual cue for children, especially the younger ones, as a reminder of context.

The assignment of fixing/healing and selling conditions and the order in which the children were presented the mechanistic and non-mechanistic marketing information were assigned in a pseudorandom order. Because there are two conditions that the children could be assigned to (fixing/healing or selling) and two orders in which participants could be given the information (mechanistic information first or marketing information first), there were four ways that participants could be tested: (1) fixing/healing with mechanistic information presented first; (2) fixing/healing with non-mechanistic marketing information presented first; (3) selling with mechanistic information presented first; and (4) selling with non-mechanistic marketing information presented first. To randomize the order in which the four artifacts were presented, all four stories were put in an envelope and they were pulled out one by one.

3.4 Results

Scoring. Scoring was performed the same way as for the adults, with a possible score of 0-1 for each item, 0-2 for each category (mechanical devices v. biological entities) and an overall score of 0-4.

Gender and order. **5- to 7-year-olds:** For fixing, there was not a significant gender difference in preferring mechanistic information, all $t(28/30) < 1.17$, $p > .25$. For selling, there was a slight trend of girls preferring mechanistic information, all $t(22/24) < 1.76$, $p > .09$. There was no significant effect of order of presentation (whether participants were first presented with the individual with mechanistic information or the individual with non-mechanistic information) within conditions, all $t(40/42) < 1.23$, $p > .23$. **8- to 10-year-olds***:* For fixing, there was not a significant gender difference in preferring mechanistic information, all $t(10/12) < 1.41$, $p > .19$. For selling, boys preferred having mechanistic information significantly more than did girls, all $t(18/20) < 2.60$, $p < .02$. There was no significant effect of order of presentation within conditions, all $t(30/32) < 1.65$, $p > .12$.

Fix condition. **5-7:** Figure 3 shows the mean category scores for the fix condition (0-2) and Figure 4 shows the mean scores by item (0-1). One sample t-tests with a test value of 1 showed that for both categories of items (mechanical and biological), 5- to 7-year olds were more likely than chance to choose the mechanistic response, both $t(29) > 4.07$, $p < .001$. Within the individual items, participants were above chance in selecting the mechanistic response when asked about fixing a refrigerator and healing a goldfish, both one sample $t(29) > 4.82$, $p < .001$, test value = 0.5. However, they did not significantly differ from chance in selecting the mechanistic response when asked about fixing a hoverboard and healing a Venus flytrap, both one sample $t(29) > 1.49$, $p > .14$, test value = 0.5. A paired sample t-test revealed that the endorsement of mechanism did not differ between the two categories (mechanical v. biological), with mean scores for both categories being identical. Finally, the mean total score (0-4, $M = 2.93$, $SD = 0.87$) for the fix condition was significantly above chance, $t(29) = 5.89$, $p <. 001$, test value = 2. **8-10:** Figure 5 shows the mean category scores for the fix condition (0-2) and Figure 6 shows the mean scores by item (0-1). One sample t-tests with a test value of 1 showed that for both categories of items, 8- to 10-year olds were more likely than chance to choose the mechanistic response, both $t(11) > 5.75$, $p < .001$, also being above chance in selecting the mechanistic response for all individual items, all one sample $t(11) > 2.97$, $p < .013$, test value = 0.5. A paired sample t-test revealed that the endorsement of mechanism did not differ between both categories of items, $t(11) = 1.48$, $p = .166$. Finally, the mean total score (0-4, $M = 3.67$, $SD = 0.19$) for the fix condition was significantly above chance, $t(11) = 8.86$, $p <. 001$, test value = 2.

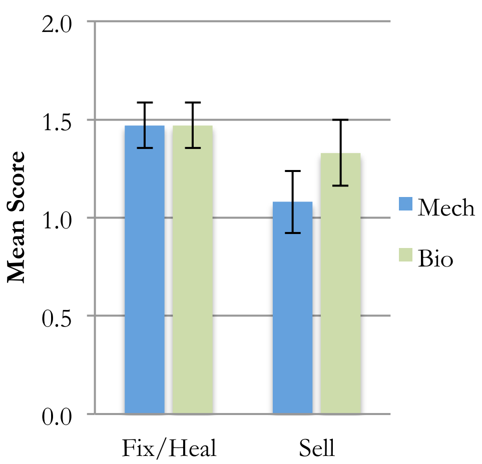


Figure 3. 5-7-year-olds Mean Scores by Item Category

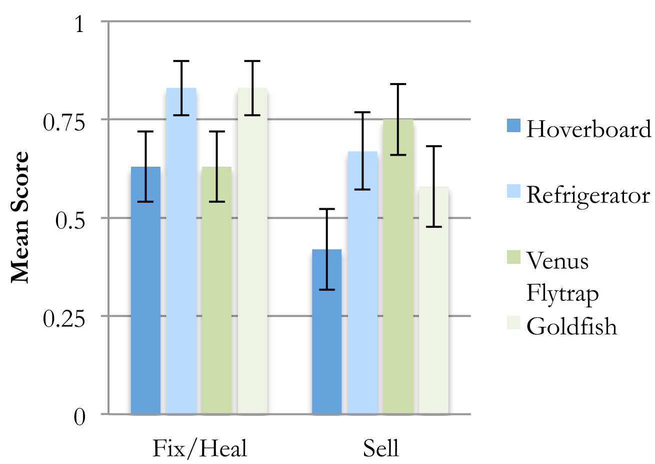


Figure 4. 5-7-year-olds Mean Scores by Item

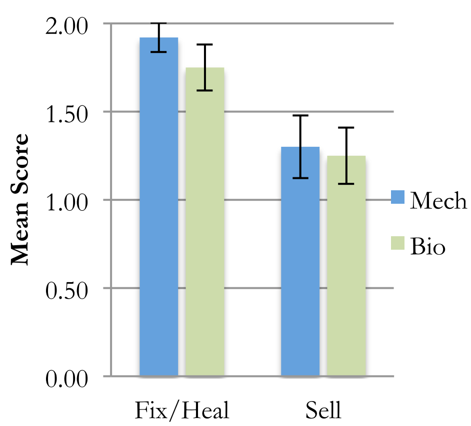


Figure 5. 8-10-year-olds Mean Scores by Item Category

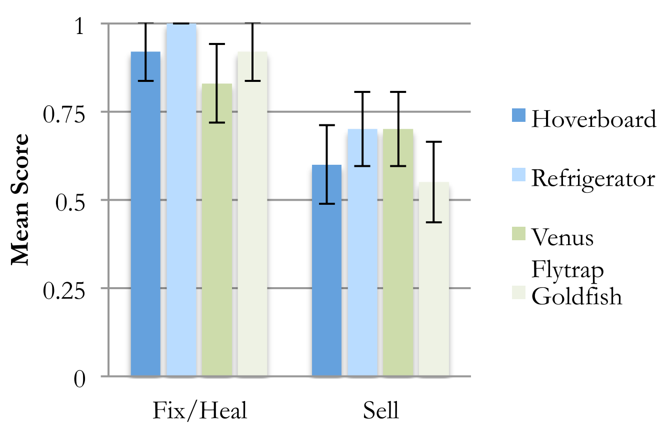


Figure 6. 8-10-year-olds Mean Scores by Item

Sell condition. **5-7:** Fig. 3 shows the mean category scores for the Sell condition (0-2) and Fig. 4 shows the mean scores by item (0-1). One sample t-tests with a test value of 2 revealed that for mechanical devices, participants did not significantly differ from chance in their endorsement of mechanism, $t(23) = .526$, $p = .604$. However, for biological entities, participants were slightly above chance in their endorsement of mechanism, $t(23) = 2.00$, $p = .057$. A paired sample t-test showed that there was not a significant difference between participants' endorsement of mechanism for mechanical devices and for biological entities, $t(23) = 1.19$, $p = .247$. One sample t-tests showed that participants were at chance in selecting between the mechanistic and non-mechanistic marketing response for all items (all $t(23) < 1.70$, $p > .10$, test value = 0.5), except the Venus flytrap, for which participants picked mechanism above chance $t(23) = 2.77$, $p = .011$. Looking at mean total scores, participants overall showed a trend of preferring mechanistic responses in the sell condition, $t(23) = 1.68$, $p =.106$, $M = 2.42$, $SD = 1.21$, test value = 2. **8-10:** Fig. 5 shows the mean category scores for the sell condition (0-2) and Fig. 6 shows the mean scores by item (0-1). One sample t-tests with a test value of 2 revealed that for both categories of artifacts, participants did not significantly differ from chance in their endorsement of mechanism, $t(19) > 1.56$, $p > .11$. A paired sample t-test showed that there was not a significant difference between participants' endorsement of mechanism for mechanical devices vs. for biological entities, $t(19) = 0.271$, $p = .789$. One sample t-tests showed that participants were at chance in selecting between the mechanistic and non-mechanistic marketing response for selling hoverboards and goldfish (both $t(19) < .44$, $p > .39$, test value = 0.5), but showed a trend in preferring mechanistic information for refrigerators and Venus flytraps (both $t(19) = 1.90$, $p = .072$). Looking at mean total scores, participants overall showed a trend of preferring mechanistic responses in the Sell condition, $t(19) = 1.93$, $p = .069$, $M = 2.55$, $SD = 1.28$, test value = 2.

Fix v. Sell Condition. **5-7:** Independent sample t-tests found that participants showed a trend of being more likely to choose the mechanistic response in the fix condition than in the sell condition for the category of mechanical objects and for goldfish, all $t(52) > 1.82$, $p < .08$. Participants were not significantly more likely to choose the mechanistic response in the fix condition than in the sell condition for the category of biological entities, as well as for hoverboards, refrigerators, and Venus flytraps, all $t(52) > 0.67$, $p > .12$. **8-10:** Independent sample t-tests found that participants were significantly more likely to choose the mechanistic response in the fix condition than in the sell condition overall, for both categories of items, and refrigerators and goldfish, all $t(30) > 2.16$, $p < .04$. They showed a trend of being more likely to choose the mechanistic response in the fix condition than in the sell condition for hoverboards, $t(30) = 1.99$, $p = .056$, and were not significantly more likely to the mechanistic response in the fix condition than in the sell condition for Venus flytraps, all $t(30) = .826$, $p = .415$.

5-7 v. 8-10 v. Adults. See Figures 7 and 8 for comparisons by age group. **Fixing:** One-way between-subjects ANOVAs were conducted to compare the effect of age group on preference for mechanistic information in the fix condition, for the 5-7, 8-10, and adult participant groups. There was no significant effect of age on preference for mechanistic information overall ($F(2, 96) = 2.05$, $p = .135$), for both mechanical and biological artifacts (both $F(2, 96) > 1.11$, $p > .124$), and for all items (all $F(2, 96) > .56$, $p > .108$), except for the Venus flytrap which showed a trend of 8-10-year-olds and adults preferring mechanistic information to heal them, more than 5-7-year-olds had this preference ($F(2, 96) = 2.66$, $p = .075$). **Selling:** One-way between-subjects ANOVAs were conducted to compare the effect of age group on preference for mechanistic information in the sell condition. There was a significant effect of age on preference for mechanistic information overall ($F(2, 100) = 14.1$, $p < 0.001$), with 5-7-year-olds and 8-10-year-olds both preferring mechanistic information significantly more than did adults, but with no difference between the two child age groups. This effect also held true for the group of biological entities, ($F(2, 100) = 14.6$, $p < 0.001$. For the group of mechanical objects, 8-10-year-olds preferred mechanistic information significantly more than did 5-7-year-olds, who preferred it more than did adults, $F(2, 100) = 6.30$, $p < 0.003$.

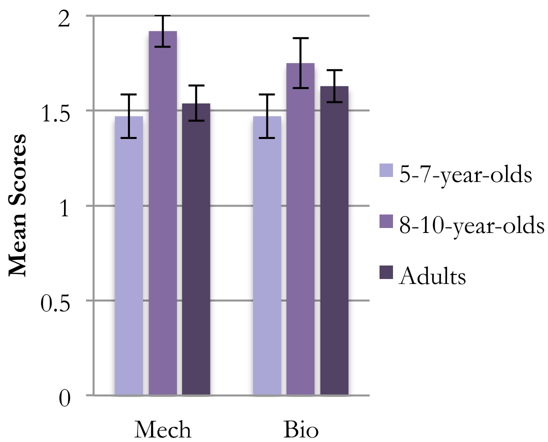


Figure 7. Fixing – Mean Scores by Age

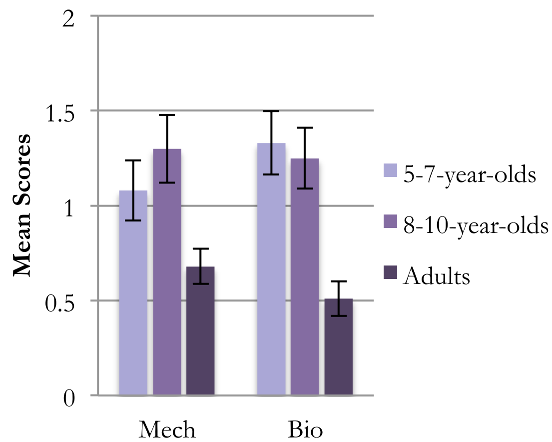


Figure 8. Selling – Mean Scores by Age

3.5 Discussion

Overall, children showed strong preferences for mechanistic information, and were less sensitive to context than we anticipated. 5-7-year-olds overall significantly preferred having mechanistic information when asked to fix or heal something, and showed a trend of preferring mechanistic information when asked to sell something. 8-10-year-olds also displayed the same overall preferences.

For the fixing condition, there was a significant preference for mechanistic information across all three age groups, both when looking at total scores and scores by item category (mechanical and biological). There were a few individual items for which preference did not significantly differ from chance, but for the majority of the individual items, participants significantly preferred having mechanistic information. Children demonstrated some understanding of the demands of the context of fixing/healing: to justify picking the individual with mechanistic information, some gave responses similar to, “he knows how [the hoverboard] works and can most likely repair it”. However, most justified their choices by personal preference and importance of information, saying things like, “I want to know…” or “I don’t want to learn about…”, or saying that the mechanistic information was “more important”. Thus, their sensitivity to context was limited.

For the selling condition, there was an overall trend of preferring mechanistic information for both 5-7-year-olds and 8-10-year-olds, though for some individual items or item categories, participants did not significantly differ from chance in their preference for mechanistic information. By comparison, for adults, there was a significant preference overall, by item category, and across all four items for non-mechanistic marketing information. A small number of children, mostly the 8-10-year-olds, did choose the non-mechanistic marketing information and explain their choices in terms of what they thought customers would want to know. One 4th-grader who chose non-mechanistic marketing information for selling goldfish explained his choice by saying, “Customers would want to learn about taking care of goldfish, not what’s inside them.” Another, when asked about selling refrigerators, said, “Someone might want a big or a small refrigerator.” However, similarly to child participants in the fixing condition, most explained that they made their choices based on their personal preferences and opinions, rather than based on what they thought the context required. Children also might have chosen the marketing information less than the mechanistic information because they have a limited conception of what constitutes effective marketing. Young children have difficulty grasping the persuasive intent of advertisements (Calvert, 2008), and similarly, might not yet understand how to best sell something, either from lack of exposure or not having yet developed in this capacity.

There were no significant gender effects in any of the age groups under any of the conditions except for with 8-10-year-olds in the selling condition: 8-10-year-old boys preferred having mechanistic information significantly more than did girls. This could suggest that girls develop earlier than do boys in terms of context sensitivity. Theory of mind research suggests that among young children, girls outperform boys in theory of mind tasks (Walker, 2005; Calero, Salles, Semelman, & Sigman, 2013). While the ability to take into context is perhaps not directly associated with theory of mind, being able to discern between subjective and objective opinions, especially when the two are in tension, is related to theory of mind, and is what is required for children in the selling condition. Thus, this result for 8-10-year-olds in the selling condition fits into what we know from theory of mind research.

The results of Experiment 2 suggest that children have a strong preference for mechanistic information, and also that children are largely immune to contextual demands when problem solving. Beyond this, however, these results may also suggest something about children's beliefs about expertise, namely that those who know more complex information will by virtue of their expertise also know less complex information. For instance, if children believe that mechanistic information on refrigerators is more complex than marketing information, they might also believe that the individual who knows the mechanistic information also knows the marketing information. Children have been shown to be able to distinguish between knowledge that can be directly acquired through perception or personal experience and knowledge that must be indirectly acquired through learning from others (Keil, 2012; Lockhart, Goddu, Smith, & Keil, 2015). Thus, in the present study, the child participants may have assumed that because marketing information often involves the features of entities (e.g. the different models of refrigerators) and mechanistic information tends to involve internal features (e.g. the pipes inside a refrigerator), they are able to learn about marketing information on their own, while they would need the help of an expert to learn about mechanism.

Prior studies looking at children's beliefs on experts have also demonstrated that children do have different expectations for what they believe different experts know. Children impose epistemic limits on what they expect experts to know, and are at least somewhat aware that expertise in one area does not necessarily mean expertise in an unrelated area (Koenig & Jaswal, 2011; Lutz & Keil, 2002). For example, when given an option to talk to adults or children, young children chose to direct food questions (why or how a particular food is good for you) to adults and toy questions (how or where to play with a toy) to children, showing that they recognized different individuals might have different levels of expertise on different subjects (VanderBorght & Jaswal, 2009). In a different study that used the context of fixing, three- and four-year-olds preferred the causal explanations for mechanical failures of toys from "fixers" (those who knew what actions could activate a toy) to those from "labelers" (those who knew the names of tools that could be used to fix toys), showing that they associated expertise in "fixing" with causal explanations (Kushnir, Vredenburgh, & Schneider, 2013). Four-year-olds also used experts who knew about the insides of objects as sources of knowledge for the names of those objects, but not experts who knew about the outsides of objects (Sobel & Corriveau, 2010). Therefore, children might have preferred talking to the individual with mechanistic information because they assumed that person was a more reliable source, given that mechanism typically deals with the "insides" of artifacts, and non-mechanistic marketing information with "outside" physical features. This issue of mechanism and expertise is worth exploring in further studies, or could be addressed with the design of the present study by asking child participants follow-up questions such as, "Do you think Mr. Smith (individual with mechanistic information) also knew about the things Mr. Jones (individual with non-mechanistic marketing information) was talking about? Do you think Mr. Jones knew about the things Mr. Smith was talking about?" to see if children assumed that the individual with the mechanistic information also knew all the non-mechanistic information, and vice versa.

4. General Discussion

In Experiment 1, adult participants preferred having mechanistic information to help them fix or heal artifacts and preferred having non-mechanistic marketing information to help them sell artifacts. These findings suggest that participants were sensitive to context, understanding that the most helpful type of information when solving a problem would depend on the goal of the problem. By contrast, in Experiment 2, child participants preferred having mechanistic information to help them fix or heal artifacts and overall, had a slight preference for mechanistic information to help them sell artifacts. This finding supports the previous body of literature demonstrating that children have a strong interest in and preference for causal mechanism, and suggests that this preference may be so strong as to override the context in which the preference is being considered. The ability to change one's judgment of the importance of information based on context, or perhaps even more generally the ability to consider context when problem-solving, seems to be something that develops with age for children, and is certainly still at its early stages of development, even for 10-year-olds, the oldest children in our study.

4.1 Limitations

1. The group of child participants in the study came from three different contexts: a children's museum in New Haven, a children's museum in Norwalk, and an elementary school in Waterbury. Because these three contexts and towns are so different, they inevitably give rise to very different groups of children, namely with respect to race and socioeconomic status. Because we collapsed the data across all child participants to obtain a large enough sample size, regardless of where they were tested, any differences that were site-specific could have been masked. The way to address this potential issue would be to obtain a large enough sample from one of the three contexts, or to choose contexts that were more similar. We were limited in time and availability of child participants, and recognize that this as a potential limitation of the study.

2. In terms of experimental design, a potential limitation exists in that the study was set up so that participants answered questions of "what would *you* do" as opposed to "what should *someone else* do". This presents a greater issue with the child participants rather than the adults. For children, particularly young children, distinguishing between the subjective and objective is challenging, if not impossible (Burr & Hofer, 2002; Kuhn, Cheney, & Weinstock, 2000). By posing questions as questions of personal opinion, it becomes potentially even more difficult for them to ignore their baseline interests and preferences and to consider the context in which the questions are being asked. By framing the questions in terms of asking what another person or child should do, this issue could have been avoided, or at least mitigated. Indeed, during the study, many children justified their answers in terms of what they wanted to learn, or what they thought was most interesting. However, if the questions were framed differently, to ask as what type of information the child thinks another individual would prefer in this context, he or she might be more likely to consider the context, rather than answer based solely on their own context-independent preferences. It is possible that even with this modified phrasing, children would still have difficulties considering context, but it seems likely that removing the subjectivity in this questions would be helpful.

3. Another point on design: We could have counterbalanced and controlled various factors in the experiment more precisely. Most of these details are minor: counterbalancing the two images of the individuals presenting the information for each stimulus and having the exact same number of words in the mechanistic and marketing information for each stimulus (the numbers of words are closely, but not exactly matched.) At the same time, we recognize that counterbalancing is a crucial part of designing elegant and carefully controlled experiments, and something that could be improved upon for future follow-ups to this experiment.

5. Conclusions and Future Directions

The present study demonstrates children's strong preference for mechanism – a preference that overrides context – and that they are not very sensitive to contextual demands. Further research in this domain might involve other studies that ask children to decide between their personal preferences and what a context requires, and look into ways that can aid children in discerning between the subjective and the objective.

We hope that the results from the group of studies funded by the NSF grant, which includes the present study and the other studies examining children's perceptions of mechanism, are able to better inform the pedagogy and practice of science and technology education in schools. If indeed, as the present study suggests, children have a strong preference for mechanism that is mostly context-independent, altering STEM curricula to best teach based on the way children best learn and process could be useful. On the other hand, understanding context is a necessary and relevant part of operating in the world, and doing research into ways that might prompt children to consider context is an area of future work that could produce fruitful and practical results.

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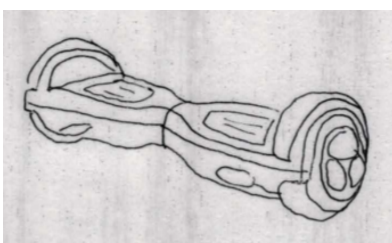
Appendix

The following four stimuli and accompanying information and questions were read by all the mTurk participants as part of their trial. For the child participants, the pictures of the stimuli and individuals with information were shown to them and the information was read to them. In the text below, it will read "fix or heal/sell" but during the experiment, participants only read or were told either "fix or heal" or "sell", based on what experimental condition they were in.

> "The following will take about 5-10 minutes to complete. You will read four short stories. In each story, you are interested in fixing or healing something. There are two people who might help you, but you can choose only one person to help you. At the end of each story I'm going to ask you to choose who would be the best person to help you fix or heal the thing. There are no right or wrong answers – I just want to know what you think."

Hoverboards

"You are interested in fixing/selling hoverboards. Hoverboards are self-balancing two wheeled scooters.



To help you, you can choose one of two people to talk to:

- Mr. Jones has information about the following kinds of things. He can tell you about the kinds of batteries you need to power hoverboards. He also can inform you about how the motor works that pushes the hoverboards. Finally, he can tell you about the sensors that keep the hoverboards balanced.

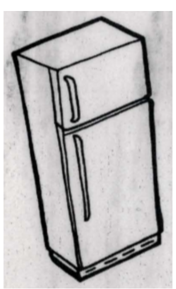
- Mr. Smith has information about the following kinds of things. He can tell you about the various colors that hoverboards can come be. He can also inform you about how hoverboards can vary in size and how some hoverboards can have lights. Finally, he can tell you about where it is okay to ride and use hoverboards.

If you could only choose one person to help you, which person would be the most helpful if you wanted to fix/sell hover boards?

- Mr. Jones, who can tell you about the kinds of batteries hoverboards use, how motors work in hover boards, and also about how the sensors keep them balanced, or
- Mr. Smith, who can tell you about all the colors hoverboards can be, about the different sizes of hover boards and the kinds of lights they might have, and also where you can use them."

Refrigerators

"You are interested in fixing/selling refrigerators. Refrigerators are household machines that store food at cold temperatures.



To help you, you can choose one of two people to talk to:

- Mrs. Miller has information about the following kinds of things. She can tell you about how the thermostat controls the temperature in the refrigerator. She can also inform you about the pipes that exchange hot air with cold air. Finally, she can tell you about the special liquid that helps to cool the refrigerator.

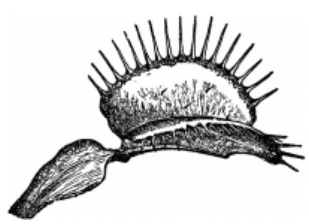
- Mrs. Wilson has information about the following kinds of things. She can tell you about what kind of refrigerators have freezers on the bottom and what kinds have freezers on the top. She also can inform you about the different sizes refrigerators can be. Finally, she can tell you about the number and kinds of drawers and shelves that refrigerators can have.

If you could only choose one person to help you, which person would be the most helpful if you wanted to fix/sell refrigerators?

- Mrs. Miller, who can tell you about how the thermostat controls the temperature, how the pipes exchange hot air for cool air, and also about the special liquid that helps cool refrigerators, or
- Mrs. Wilson, who can tell you about the different kinds of refrigerators, about how refrigerators can come in different sizes and also about the number and kinds of shelves and drawers refrigerators can have."

Venus flytraps

"You are interested in fixing sick/selling Venus flytraps. Venus flytraps are plants that eat insects.



To help you, you can choose one of two people to talk to:

- Mr. Taylor knows information about the following kinds of things. He can tell you about the liquid that the plant makes that attracts insects to it. He can also inform you about the trigger hairs that let the plant know when the insects have landed on it. Finally, he can tell you about how the leaves of the Venus flytrap close to catch the insects and then turn them into food for the plant.

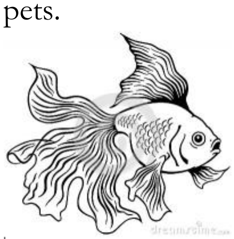
- Mr. Anderson knows information about the following kinds of things. He can tell you about what kinds of containers Venus flytraps looks most attractive in. He can also inform you about how big or small Venus flytraps might be. Finally he can tell you where you can find live insects to feed to Venus flytraps.

If you could only choose one person to help you, which person would be the most helpful if you wanted to heal/sell Venus flytraps?

- Mr. Taylor, who can tell you about the liquid that the plant uses to attract insects, how the trigger hairs know when insects are there, and also how the leaves catch and change the insects into food, or
- Mr. Anderson, who can tell you about what containers Venus flytraps look best in, about the different sizes of Venus flytraps, and also about where you can find live insects to feed to Venus flytraps."

Goldfish

"You are interested in healing sick/selling goldfish. Goldfish are fish that are often kept as pets.



To help you, you can choose one of two people to talk to:

- Mrs. Williams knows information about the following kinds of things. She can tell you about how goldfish breathe underwater. She can also inform you about how goldfish stay underwater using a special part that gets bigger or smaller depending on how deep in the water the fish goes. Finally, she can tell you about how goldfish have ears inside that pick up vibrations and sounds.

- Mrs. Davis knows information about the following kinds of things. She can tell you about how goldfish come in all sorts of shapes and types – some are sleek, some are chubby, and some have few fins, some have many fins. She can also inform you about all different colors and patterns that goldfish can be. Finally, she can tell you about what decorations are best to put in the aquariums of goldfish.

If you could only choose one person to help you, which person would be the most helpful if you wanted to heal/sell goldfish?

- Mrs. Williams, who can tell you about how goldfish breathe underwater, how goldfish stay underwater, and also how they hear, or
- Mrs. Davis, who can tell you about all the different types of goldfish, about all the different colors and patterns of goldfish, and also about the best decorations to put in goldfish aquariums."