COLLEGE STUDENTS' IDEAS ABOUT SOME EVERYDAY ELECTRICAL DEVICES

Educators have often attempted to motivate students' interest in science by demonstrating its connection to everyday life. This research focuses on whether exploring the topic of electricity within the context of common electrical devices would make learning more enjoyable and productive for introductory college students. In Phase I of the research, students were asked which electrical devices they found interesting and to explain the functioning of those devices. A wide variability in devices cited by the students was observed, with students focusing mainly on electronic devices and usability. In Phase II, students' conceptions of the functioning of a blender were investigated and hands-on interactive demonstrations were introduced to help students to construct a mental model of an electromagnetic motor used in a blender.

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Background and Introduction

Research shows that learners are increasingly motivated when they see the usefulness of what they are learning and apply it to everyday life. (McCombs, 1996; Pintrich, 1996) White (White, 1959) describes how "competence motivation" often translates into a greater amount of time and effort that students are willing to devote to learning. When Barlia and Beeth (Barlia, 1999) created individual motivational profiles for students in a calculus-based course, they found that "task value" was the principal motivational factor to promote conceptual change. Studies (Duch, 1996; Ferguson, 1995; Rennie, 1996) that compared student learning and performance on tasks with and without real-world contexts found that student learning was enhanced by real-life contexts. These findings indicate that teachers need to enable students to connect their learning to everyday life. Electrical devices ranging from cell phones to TVs to computers are ubiquitous in students' everyday lives. This research focuses on exploring the use of these devices to enhance student learning. Before developing instructional materials that use electrical devices, we needed to explore the devices that students found most interesting and liked to learn more about. We also needed to explore the ideas about these devices that students would bring to the classroom based on their past experiences. Our research questions were:

1) What everyday electrical devices do students find interesting and what do they know about these devices?

2) What are students' ideas about how some particular devices work and what instructional strategies can be developed to facilitate them to construct their understanding about these devices?

Theoretical Underpinnings

Our study is based on the premise that students are motivated to learn when they see connections between what is taught in class to their everyday life. We are interested in exploring the extent to which students can transfer their learning from the classroom to everyday electrical devices and vice versa. Therefore, the theories of transfer of learning and constructivism formed the important underpinnings of our research. Transfer is often defined as the ability to apply what was learned in one context to a new context. (Byrnes, 1996) Contemporary perspectives describe transfer as a dynamic construction of associations between the two contexts mediated by several factors. (Rebello *et. al.*., 2005) In this project we examined transfer of learning from Lobato's actor-oriented perspective. (Lobato, 2003)In short, we did not predetermine what a student should transfer, but rather examined everything students transferred to the situation including spontaneous intuitive knowledge as described by Hammer (Hammer & Elby, 2002) and attunement to the affordances as described by Greeno. (Greeno, Moore, & Smith, 1993) These contemporary perspectives of transfer of learning are consistent with the notion that learners construct their own knowledge. Piaget (Piaget, 1964) suggests the use of strategies such as cognitive conflict to promote students' intellectual development. Vygotsky (Vygotsky, 1978) focuses on learning within a "zone of proximal development" facilitated by interactions with more capable individuals.

Methodology

A multi-methodological framework was developed by adapting grounded theory (Holloway, 1997; Strauss & Corbin, 1998)and phenomenological approaches. (Holloway, 1997; Marton, 1986) This framework was designed to progress in time by casting a wide research net followed by a more focused investigation. Our research evolved over two phases, corresponding to each of the research questions above.

In Phase I -- the fact-finding phase -- we explored which electrical devices students find interesting and would like to learn more about and what their initial thoughts on those devices were. We approached this investigation using a grounded theory approach in that we did not have any prior hypothesis about what everyday electrical devices students might find interesting, rather we cast a wide net to explore any possible devices that students might mention. We used a cyclic sequence of open and axial coding through constant comparison until saturation was achieved. Categories and themes emerged from students' responses through the process of selective coding. A total of 12 non-science students were interviewed in this phase.

In Phase II, we focused on a single device – the blender. The device was chosen based on the results of Phase I (discussed later). We conducted semi-structured, individual teaching interviews, (Engelhardt, Corpuz, Ozimek, & Rebello, 2003) more commonly known as teaching experiments. (Steffe & Thompson, 2000) The teaching interview is a mock instructional setting that focuses on students' sense making processes rather than their pre-conceptions. The interviewer is also a mock instructor who facilitates students' conceptual change and learning during the interview. Underlying the teaching interview is a belief that most students may not have well formed ideas about how a blender works.

Rather, when asked, they construct their ideas on the spot. To understand the process by which students can construct their ideas we provide them with graduated scaffolding through hands-on activities and prompting questions and observe the process as they think aloud while constructing their ideas. The scaffolding and questions that students rely on to construct their ideas helps us develop instructional materials. The interviews were analyzed using a phenomenological approach which is consistent with the theoretical underpinnings of contemporary transfer. Fifteen non-science majors were interviewed in this phase.

Phase I Results

The following themes emerged when we analyzed students' responses in Phase I.

Variability: There was a variable level of interest in learning about electrical devices, with some students claiming that they were extremely interested, while others claimed that learning about everyday electrical devices was not likely to pique their interest.

Electronic Devices: Almost all of the devices mentioned by students were electronic, rather than electrical devices. Perhaps using the term "electrical appliances" rather than "electrical devices" in the in the interview question may have yielded different results. The electronic devices mentioned by students included most often computers and computer accessories. Several students also mentioned modern gadgets such as the CD-player or cell phone. They could not offer any compelling reasons for why electronic devices were most interesting. Responses such as "I kind of am actually… I don't know why I would be about a computer and not these…" were common.

Usability: When asked what students would like to learn about the device that they had cited as interesting, their responses often focused on the usability of the device rather than the physical underpinnings of how the device worked. A response such as "Like, what can I do with them? I'm not so concerned with what's in them" was typical among students.

Given the large variability in the devices and interest level we decided that it would be most appropriate for us to select a device by ourselves. In choosing a device we used a list of criteria similar to those used by Bloomfield. (Bloomfield, 2001) We chose a blender for the following reasons:

1) Most students are familiar with the blender and have either used or seen someone use the device.

2) The physics of electric motors that form the blender is covered in the standard introductory undergraduate physics curriculum. Thus, instructional materials ultimately developed through our research could be adopted in a typical physics course.

3) The physics concepts underlying a blender, i.e. the physics of an electric motor, are common to several everyday devices such as a washing machine, toy cars and even in more modern devices such as computer hard disks or CD players.

Phase II Results

In Phase II, we first began by asking students to describe how a blender worked. Most students responded by stating that they had “no idea.” A few students mentioned that it had an “electric motor” inside, but they could not explain it any further. We showed students a blender with a portion of the side panel cut out so (Figure. 1) that they could look inside when the blender was running. They focused on the sparks and the rotating parts. Viewing the inside of a running blender did not help them explain how it worked.

Figure 1: Blender with cut-out view for students to see inside when motor is running

Next we showed students the internal parts of a blender that had been taken apart. (Figure 2) These parts included the rotor, stator and the switch. Most students were able to recognize from their earlier observation that the rotor was the spinning part. However, in describing the functionality of the other pieces, they tended to focus on the structure of each piece. For instance, one student looked at the switch (Figure 2) and noted that “I would guess that this is something that would hold like if you had batteries or something because of the spring.” This response appears to indicate a reasoning based on the structure, rather than thinking about how the piece facilitates the functioning of the blender.

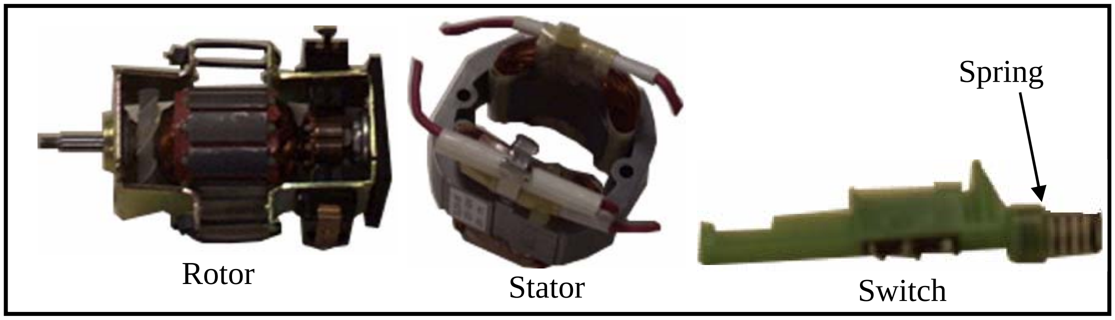

Figure 2: Internal parts of the blender that were shown to the students

We then progressed toward a teaching interview in which we provided increasing scaffolding to enable students to construct a model of how a blender worked. We used a series of activities, some of which were adapted from lecture demonstrations or lab experiments. We began with activities that shared the same conceptual basis, but had nothing structurally similar to the blender. We then progressed to activities that shared both the conceptual underpinnings as well as some structural similarities with the blender. The sequencing was designed to provide graduated prompting starting from the abstract and general prompts to more concrete and specific prompts. We attempted to gauge the extent to which students have to be prompted to construct a model of how the blender works. Thus, for each demonstration we asked students to 1) predict how they would get the motor to run, 2) explain their prediction and observations and 3) reflect on how the demo was related to the blender.

We began by using a rail-gun (Figure 3), which about half of the interviewed students should have been exposed to in the classroom. However, virtually no one claimed to be familiar with it. Students were urged to use a paper clip to identify various parts of the rail gun and quickly realized that there was a magnet in the center. When asked to predict what would happen if a battery were connected to the posts, most students predicted that the rod that spanned the two beams would rise up on one side because of the magnetic field. When they tested their prediction and observed that the rod moved along the rails, they explained this as attraction or repulsion from the “charges” that were being supplied to the posts. When asked what would happen if we switched the polarity of the battery, most students responded that the direction of motion of the rod would reverse. Students appeared to be using an intuitive p-prim based reasoning when they arrived at this conclusion, rather than an understanding of how the rail-gun worked. (diSessa, 1988) Most students did not see any connection with the blender. A few pointed out that similar to the rail-gun, the spinning of the blender rotor too must be due to attraction.

Figure 3: The rail gun

Next we provided students with a simple canister (Figure 4) motor often used in battery operated toy cars. Students intuitively knew where to connect the battery. They predicted that the direction of rotation would reverse if the polarity of the battery were reversed. They took the motor apart to explain the various parts and soon realized that the magnetic case was essential to making it turn because it would not turn when it was taken out of the case. However, they were unable to explain why the magnet was essential. When asked about the relationship to the blender the students pointed out that the motor was a smaller version of the blender motor. When asked about the differences they focused on the structural differences but also noted that they could not locate the magnet in the blender. This activity provided students with the necessary disequilibrium to motivate them to figure out how a blender really worked, because they realized that although it behaved similarly to a canister motor, it did not have one essential part – the magnet.

Figure 4: The canister motor

In the next activity, students moved to a motor assembly that we had constructed on a flat wooden board. The assembly consisted of the rotor of the canister motor along with two permanent magnets on either side of the rotor. (Figure 5) The connections to the rotor were now clearly visible to the students.

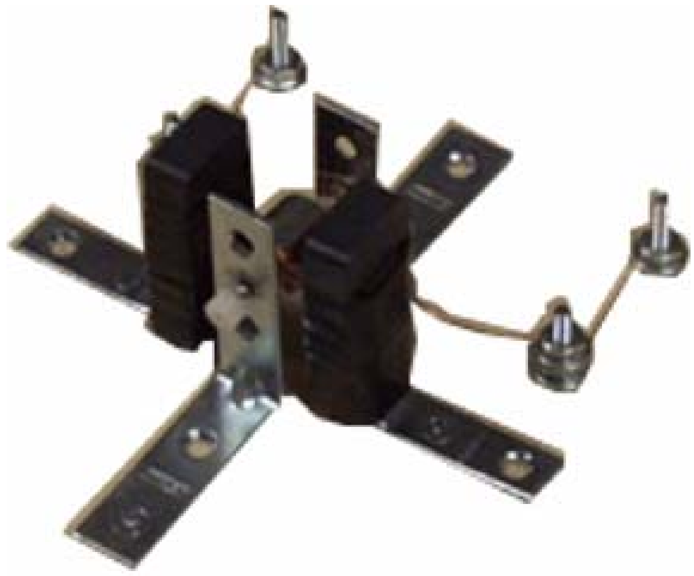

Figure 5: The magnet motor

Most students predicted that the motor would turn when the magnets were attached to the screw posts. Some students initially thought the permanent magnets were bumpers, but when asked to test the system with a paper clip as they had done before, they quickly realized that they were magnets. The presence of these magnets helped students connect the board magnet motor to the canister motor. However, unlike the canister motor, this motor was more clearly visible to the students since all the parts were in clear view of the students. Therefore, they were able to construct more elaborate (though not necessarily scientifically correct) explanations of how the motor works. In general their explanations focused on energy or current going through the wires and causing the motor to spin. In comparing with the blender, students again focused on the surface similarities – the copper wires and the segmentation of the plates on the rotor surface. The differences focused on surface features and the absence of a magnet in the blender.

All of the demonstrations so far contained a magnet – a component that was missing from the blender. Students could not explain why the blender turned although there was no magnet in it. The next and final activity helped students construct an explanation. This setup (Figure 6) was identical to the previous demonstration; however, instead of using permanent magnets, this demo used two electromagnets. Students' first task was to make the motor turn by appropriately connecting batteries to the various posts and then explaining why the motor turned.

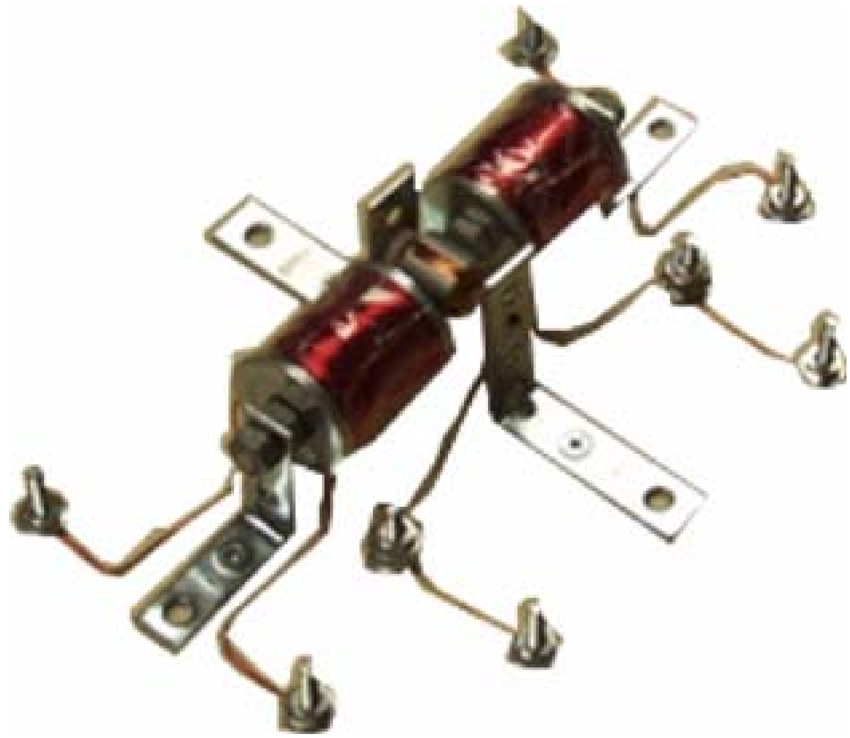

Figure 6: The coil motor

Students began by first connecting only the rotor to the battery, just as they had in the previous activity. From the perspective of Greeno's theory of transfer of situated learning, (Greeno et. al.., 1993) the students appeared to be "attuned to the affordances" of the new demonstration based on their previous demonstration. They soon realized, however, that the motor would not turn in this case. Some students moved the connections to the posts that were closer to the coil, which can be interpreted in terms of a p-prim-based reasoning that "closer is stronger." Eventually, with some prompting almost all of the students were able to recognize that they needed to connect the electromagnet coils to the battery. They also recognized that connecting both coils would either make the motor stop completely or speed up, depending upon how the coils were connected. Most students were able to explain this, again in terms of p-prim-based reasoning of the coils "canceling out" or "adding up." When asked to explain why the rotor turned when the coils were connected, the students explained it in terms of the coil giving the rotor some kind of push. Several of the students were able to recognize that the coils in fact acted as a magnet. For those who were unable to recognize this similarity, we had them use a separate solenoid, pass current through it and observe how it deflected a magnetic compass the same way that a magnet did. This helped students recognize that the coils were in fact acting as magnets. When asked to compare this set up with a blender, students were able to recognize that the coils in this demo were similar to coils in the blender and functional similarities between the two. However, students were still unable to give a clear explanation of why the rotor turned.

Conclusions

When asked at the end of all of the activities, students ranked this last activity as being most useful in helping them understand the blender. They were nearly unanimous in stating that the rail-gun activity was least useful. They also appeared to prefer the existing sequence of demos. It was not the goal of this research to ascertain whether students had the correct scientific understanding of the blender or even motors in general. Rather we focused on the knowledge construction and the types of reasoning used in the process by students. The following themes emerged in Phase II:

1. Epistemic mode: knowledge is "self-constructed" (Hammer & Elby, 2002) Almost all students, regardless of their prior knowledge appeared to be comfortable constructing their own knowledge. They were willing to make predictions and figure things out even though they may not have known the answers beforehand.

2. Intuition-based reasoning: Because students were unable to resort to their knowledge of electrical machines they often resorted to intuition based on p-prims (diSessa, 1988) or based on their attunement to the affordances of the system. (Greeno et. al.., 1993) In almost all instances, this intuitive reasoning helped the students arrive at the scientifically correct answer. However, in the future we would like to have students build on this reasoning while constructing their explanations.

3. Structure over function: (Mestre, 1994) Students tended to focus on the structural similarities and differences between the various demonstrations. In a few instances, this reasoning was productive, while in other cases it was not. In general, we hope to facilitate students' transition to looking beyond the surface features, at the underlying functionality, while comparing devices.

4. Confusion between charges and magnetism: In describing the role of the magnet in making the motor turn, most students described the magnet as being charged. It appeared that they were unable to distinguish between electricity and magnetism, a misconception that has previously been reported by Maloney and co-workers. (Maloney, O'Kuma, Heiggelke, & Van Heuvelen, 2001)

5. Wide spectrum of models: Students constructed a variety of models to explain why the motor turned. These ranged from naïve, mechanically-based models that stated that "charges bounced off the magnets and rotor" to cause the rotor to spin, to those that were closer to the scientifically accepted models, which attributed the rotation to "attraction between the magnets and rotor." There were also hybrid models (Hrepic, Zollman, & Rebello, 2005) which combined aspects of the scientifically accepted and naïve models and stated that the motor turned because the "charges on magnets and rotor were attracted and repelled."

6. No significant differences based on education: Students who were currently taking a course in which they recently covered motors, did no better in explaining the blender than students who were not taking this course.

Our future efforts will focus on further refining the demonstrations to help facilitate student model construction and connections with concepts covered in the classroom.

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