

CHAPTER 5

ANALYSES of GROUP INTERACTIONS

The previous chapter detailed students' development of models of magnetic materials, and it provided some evidence for dialectical relationships between students' thinking about magnetism and experimental observations of magnetic phenomena. However, the students did more than simply observe a series of experimental results and produce models. The experimental observations were only part of a complex interaction of students with apparatus, with each other, and with the computer and other representational tools. The assumption of this dissertation is that interaction contributes to learning in profound ways. Chapter 4 did not offer explanations about how or why groups of students produced meaning from observations and discussions and explanations. That is the task of this chapter.

This chapter is written in three sections which correspond to research questions 2a, 2b, and 2c. The first describes a scheme for categorizing different types of activity observed in groups while they were constructing group responses. I offer connections to related theoretical frameworks at the end of this section. The second section describes a few classroom norms that were particularly relevant to the observed model development process. The final section will detail two important episodes in the video group's development of models of magnetic materials, and show the ways that classroom norms and their interactions contributed to changes in thinking.

PATTERNS OF INTERACTION DURING CONSTRUCTION OF GROUP RESPONSES

Groups spent much of their time working on computer documents. They read instructions on the screen, and they responded to "requests" in the document for predictions, explanations, diagrams, and so on. In Elicitations, group members wrote and drew group responses on whiteboards. Groups sometimes had extensive and/or fruitful discussions surrounding these events. As described in Chapter 3, this analysis characterizes episodes when members of the video group of interest were constructing group responses or preparing to do so. A "group response" was any text or picture that was taken to represent the whole group, not an individual student. Sometimes, one student would type a response without explicit comment or guidance from the other members. This was still a group response because the group members knew that the document in which their responses were made would be considered a group product. This group was not dominated by a single voice - each member had a stake in what was put into the response, because it would be printed out and each member would use it as class notes. For this and other reasons, the group members often talked at length about responses when their ideas obviously differed. Typical responses included typed predictions, explanations, and experimental results, diagrams of unmagnetized and magnetized nails, and group ideas and diagrams hand written on whiteboards.

Observed patterns

During response construction episodes, the group's activity seemed to fall into one of four major categories. Each major activity category consists of three to five subordinate categories, which together were capable of explicitly characterizing the group's activity from moment to moment.

In the analysis, each episode of discussion plus group response construction was assigned to at least one of fifteen categories of activity, plus one "miscellaneous" category. Sometimes, more than one category appropriately described the group's discussion, so more than one assignment was made at these times. The smallest episode assigned to a category was one conversational turn each by at least two speakers, or not less than about ten seconds when the students were not speaking. The longest event lasted about six minutes.

The fifteen different categories are listed in table 5.1 and detailed below.

Table 5-1: Categories of activity

Major Activity Type	Activity type
Logistics and following instructions	Recording experimental results Dealing with technical issues. "Moving on" while the typist finishes. Getting group members "on the same track" Satisfying specifications
Checking	Quiet monitoring of a response Spoken checking and joint typing Error detection and correction
Comparing within the group	Discovering <u>similarities</u> in thinking Discovering <u>differences</u> in thinking Failing to acknowledge differences in thinking
Extending ideas	Negotiating a common response from different starting points Constructing an explicit statement from talk Extending an idea into a new issue or area Exploring ideas that might be plausible Joint construction of a new idea
Other	Miscellaneous category

Logistics and following instructions

This category of activity represents the group's efforts to deal with the mechanical aspects of doing the classwork. Group activity that fits this major category was not about physics or group members' thinking. Rather, it was necessary "overhead" required to keep the group organized and productive.

Recording experimental results: Time spent recording experimental results was put into this category when the result was clear and non-controversial. If students discussed the experimental result because it was surprising or revealing, their discussion was categorized below under "Extending ideas."

Technical issues: Group members had to make layout decisions on whiteboards, and choose a writer. They had to decide who would type answers and draw pictures on the computer screen. They also sometimes encountered problems with the software, particularly in drawing pictures. These problems could use up minutes of group time, but they were often essential parts of the group's activity. In the following example, the group was working on taking a snapshot of a portion of the screen. The group members seemed to be checking that they recalled the correct keystrokes.

Donna want to take a picture?
 Marge (Alright, do ??)
 Donna kay, and then
 Marge now, what did he say?
 Anne Option, apple
 Donna Apple
 Anne shift
 Marge three- shift three.
 Donna Oops
 Anne It's fine, all right,

This is an example of the students using their actions and the state of the computer as part of the context of their communication. In this case, Anne's fingers on the keyboard indicated which keys had been agreed upon, and thus each student could check which keys had yet to be pressed. The group appropriated the positions of Anne's fingers on the keyboard as referents in their discussion.

Moving on while the typist finishes: Later in the course, as students became more familiar with the structure of the documents and when their responses were not problematic, the group members who were not engaged in typing or drawing the response would begin addressing the next task - either preparing an experiment, or addressing the next question if it was visible on the screen. The students might say something like "Okay, what do we do next?"

Getting group members on the same track: As the group moved through development documents, sometimes one member might lose track of what was going on. When asked, other group members would help get this member "back on track" by explaining and gesturing at the feature of interest on the screen or at the apparatus.

An example of this occurred when the group was explaining why they changed their model of a nail. Marge asked to be brought back on track with her group:

Donna The north, the north forces, umm, concentrated
 Marge What are we supposed to be saying? I don't remember the question

- Donna Just our rationale
 Anne Just our rationale why we're changing it.
 Marge Oh why we're changing it. Because we found
 Anne That the south . . .

Satisfying specifications: Some discussion centered on deciding what kind of response was requested. The students were addressing the question "what kind of answer do we put here?"

For example, after the video group finished doing some experiments, they were asked to re-draw their group's model diagram of a nail, but only if they had made any changes to their model. The group members had agreed to think about their separation model differently, but they had not changed their diagram on the first page of the document. The instructions read "if you have changed your model." Not all group members seemed sure how to proceed. The following discussion ensued:

- Anne Do we want to just put our exact things in there or no?
 Donna Wait are we going to have to make another picture?
 Marge We're going to revise our model. No. It says - if you - this is going to be the same as our prediction, as our first drawing. Then we take a picture of our first drawing and stick it here.
 Donna Oh, okay. but it it's not.
 Marge It's not. So we have to make a new one.
 Anne We also need to describe why we think our model needs to be modified, because there was an attraction. . . .

This group seemed to have a significant concern that they answer the written questions as well as possible. This suggests a norm which was not pursued for this dissertation. The students' apparent senses of obligation to answer correctly may have driven their frequent efforts to satisfy specifications.

Checking

This category represents a particular feature of the group's interaction with the computer or whiteboard. Because they shared a single display, the group members used it to check how their work was represented.

Quiet monitoring of a response: Group members sometimes appeared to quietly monitor or watch while another group member was typing or drawing. They watched what was being put on the screen without saying anything. The group members not typing attended to the typed answer but did not talk about it. While it is possible that group members sometimes did not pay close attention, the title "monitoring" appropriately describes the group's activity for the great majority of instances of this type of activity.

Monitoring was characterized by attention but little or no discussion by group members while work was being done. Most likely, group members either agreed with the statement, or they were not concerned with how it differed from what they thought. Many

responses were typed in this "monitoring" fashion. Episodes involving controversy or more than minimal discussion were not included in this category.

An example of monitoring occurred after the group had discussed how to draw a model of a nail, and they all seemed to agree on the major points. Anne began placing N and S letters on the nail outline, and Marge and Donna watched quietly for about thirty seconds until Donna raised a new topic of discussion.

It seems likely that some of the time, the group members were actively involved in comparing their ideas, ways of describing, or understandings with what the typist was producing. Even though the group may have been quiet during monitoring activity, the group members may have been thinking carefully. Thus, monitoring may have sometimes been a cognitive activity for some group members.

Spoken checking and joint typing: Sometimes group members explicitly read over what had just been written. Group members checked to see that what was being drawn or typed satisfied their understanding of the question, that it made sense to them, that each group member agreed with what was being produced. What differentiated "checking" from "monitoring" was the discussion within the group.

Spoken checking often took place in "real time", that is, the group would check what was currently being typed, and propose the next phrase. For instance, two group members who had just negotiated an agreement on what to type would sometimes share sentences- the keyboard operator would say or type a few words of a statement, and the other would say the next word. This collaborative filling in of sentences, or "joint typing" seemed to be a way that group members could simultaneously check that they were thinking the same way, and refine and coordinate their statements.

"Joint typing" also happened when the group was drawing diagrams. The following example occurred when Anne was drawing a picture of an unmagnetized nail by placing N and S symbols to look evenly mixed within the nail.

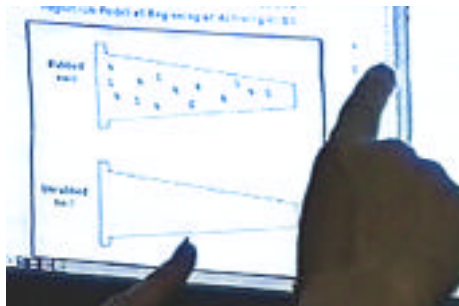


Figure 5-1: Group members pointing at nail diagrams

Anne Okay now, Ss?
 Donna That's good
 Marge Yeah
 Donna One down there, yeah.
 Marge [???] you can't delete?
 Anne Oh no, that's okay
 Anne okay. down here -

Marge Now go to the bottom. There we go.

Notice that by saying "Okay, now, Ss?" Anne made her drawing work open to the other group members, and they responded by making suggestions about placing N and S letters.

The close interaction that this category describes provided students with opportunities to coordinate not only their written words and pictures but also their understandings of the phenomenon or other students' explanations. When the group members filled in each other's sentences, this might have sometimes brought up features of the situation that one had not been thinking of. Joint typing held at least the possibility that group members could deepen their understanding.

Error correction: Sometimes group members appeared to agree on ideas about magnetism, but part of the drawing or typed response was not consistent with what they might have agreed on. In these cases, group members corrected the typist. This category was used only when the group members talked as if they agreed on the idea, and the typist had just made a mistake. If the group members appeared to actually have different ideas, their discussion was different in character (often with more complete sentences), and was categorized as "discovering differences," below.

An example of error correction happened immediately following the event shown above under "spoken checking." Anne began placing S letters at the point of a nail picture which the group agreed should be a "point - North" nail. The instructor had previously told the class that the accepted definition of a north magnetic pole (of a nail or magnet) was that it tended to point near geographic North on the Earth. Marge noticed that Anne's S letters should not be on the point of the nail that pointed towards geographic North. (Anne might have been reasoning that south poles attract north poles, so that a magnetic south pole should attract to the geographic North. Using the accepted convention, however, the magnetic pole at the geographic North pole of the Earth is a south pole. This has confused many students for many years).

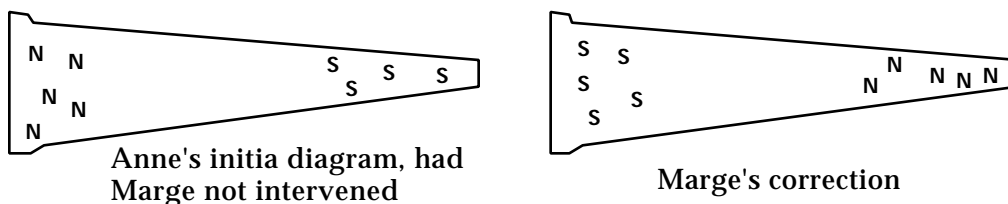


Figure 5-2: Different ideas about point - North nails

When Marge corrected Anne, both students pointed at the diagram on the screen:

Marge Now go to the bottom. There we go.
 Anne And do we want all the - okay, south ends
 Marge Want it to be a what?
 Anne south over there.
 Marge North pointing nail.
 Anne So that north's going to be - oh so we want the s-

Marge want the norths down there,
 Anne Down there. Gotcha
 Marge There. Exactly.

In Anne's first line above, her speech and manipulations on the screen informed Marge of her intentions. Marge re-read the instructions to make a point - North nail, either as a correction or to remind the group what was requested. The visibility of Anne's work on the computer screen made it easy for Marge to check what Anne was doing. This is discussed next.

Relations between computer use and checking activity

The physical configuration of the group using a computer supported checking activity. The computer screen constantly faced the students, and presented them with whatever they had typed or drawn. Group members were clearly able to see their group response as it was being created, which suggested checking and interaction. The computer offered an advantage over creating representations on paper or on a whiteboard, which was that no students' hands were in the line of vision. When one places objects on a computer screen, one's hands are not at the screen but at the keyboard or mouse. Everyone can see what is being done.

This physical separation of hands from the emerging text or diagram caused a social separation as well. The typist generally controlled the keyboard and/or mouse, but she did not have the same "ownership" of the computer screen. The outside surface of the screen remained a public space. Because of this, it seemed to be acceptable for a non-keyboard-operator to put her fingers on the screen while text was being typed. By comparison, a similar action might have been construed as interference if, say, a non-pen-operator placed her fingers on the paper that her partner was writing on. The separation of text from its creator may have encouraged more interaction between students.

Also, because the representation was being created in real time, students were able to watch it being made, and were able to intervene if they saw a problem, before the entire text or picture was finished. They were able to make comments as soon as the diagram began to look different from what they anticipated. This may have encouraged group members to be flexible in creating text and diagrams. When group members contributed to the wording of text, the result was essentially a group product.

Comparing ideas within the group

Groups faced with the task of constructing a response often began by comparing their thinking. After reading the request, one member often made a bid for discussion, saying something like "I think this," or "What do we think here?" Extensive discussions often began in the context of finding out what each group member thought would make a good response. Depending on what happened, these discussions were categorized as discovering similarities, discovering differences, or failing to discover differences.

Discovering similarities: Group members sometimes discovered after talking that their ideas were pretty similar. In this case, there was generally no problem with

predictions or explanations, and the group quickly moved to typing or drawing. Just because the group members agreed on a response, however, does not mean that careful probing by the instructor would not have revealed differences. In fact, later discussions would sometimes uncover differences in thinking when group members had earlier agreed that they thought the same. But for the categorization of a particular episode, the group was considered as having similar ideas or similar individual models.

When the group was considering what a second magnetized nail would do to a broken magnetized nail, they seemed to agree that each nail piece would only show one type of behavior. When discussing it, they had the following exchange.

- Donna I think this one [the head piece] will attract. And this one [the point piece] will repel on both sides.
- Anne 'cause this has all the norths
- Donna If you get this, or this, it's always going to, you know what I mean, it's going to attract, and this one will repel.. do you think?
- Anne I agree with you cause I don't think it's gonna change.

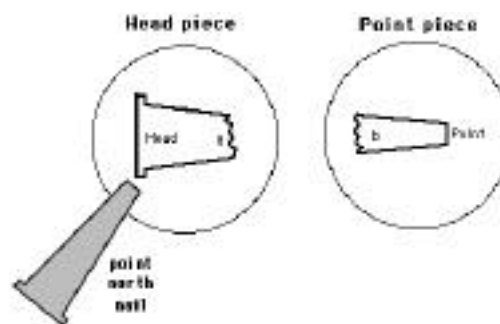


Figure 5-3: Diagrams of broken nail pieces

When group members discovered that they thought similarly about something, this tended to decrease the number of issues that group members had to address in their discussions. One can think of this as putting into Garfinkel's "reciprocity of perspectives" those issues that otherwise would have been explicit topics of conversation (Heritage, 1984, see Chapter 3). As soon as the students had a sense that they were thinking the same ways, they could drop those ideas that seemed to be "shared" from the discussion, or type them in the document, and move on. Discovering similarities allowed the group to move forward.

Failing to acknowledge differences: Sometimes group members talked as if they had similar ideas, but later events or careful scrutiny of the videotape and other data revealed that the group members actually had different ideas. The group members would say different things, but not talk about these differences, and they would accept the response on the document and move on. This of course could be considered a lost opportunity for an idea-scrutinizing discussion.

In the very first elicitation discussion, Donna and Marge expressed different ways of thinking about magnets. Marge said that magnets have positive on one end and negative on the other end. Donna did not express her idea clearly in this discussion but later explained in an interview and to Marge that she thought magnets were positive and refrigerators were negative. When Marge was drawing a picture of a refrigerator on a whiteboard, Donna raised a question:

- Donna What is a refrigerator? Is it positive or negative? or does it matter?
- Marge It doesn't matter. Because it's - since it's a metal it has both positive and negative ions in it anyway. And so it's just a random - this is charged but that is not.
[Begins drawing a picture].
- Marge [Describing as she draws a picture with both + and - signs on the refrigerator]
So this is going to have positives and negatives on it and these are going to - - so that that's this way, and then we'll have the magnet up here, with its little negative over there and its little positive over here, and he's going to be attracted this way and he'll stick.
- Marge Is that the way it's going to go?
- Donna That doesn't look like a very good
- Marge Doesn't. [erases part of the picture and re-draws]

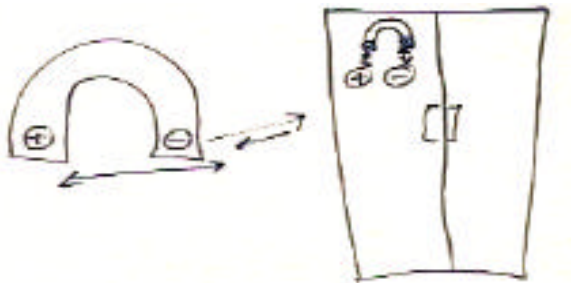


Figure 5-4: The picture Marge drew during the above discussion

After this point the two students didn't talk further about their different ideas for a model. An observer of the videotape could see that Marge and Donna had different ideas, but they didn't discuss these differences.

Interestingly, Donna was apparently listening to Marge in the above episode, because a week later she said that she understood Marge's idea about different charges at opposite ends of the magnet. At some point, Donna recognized that Marge had a different idea. The above event still is a failure to discover differences, however, because the group members did not talk about their differences at the time. Their discussions didn't show any awareness of the other's ideas, and they therefore lost the opportunity to discuss their ideas.

Discovering differences: Other times, group members figured out that they indeed had different ideas. Talking about what they wanted to put for a response sometimes led to the recognition that they were saying different things. A very important example of this happened on Day 3 when Donna and Anne found out that Marge didn't think that static electricity was caused by processes similar to what caused magnetism. Here is part of their discussion:

- Marge You're saying that the straw is being made positive.
I don't think it's being made positive and I don't think metals are all negative.
- Donna The wool rubbed straw is a positive, creates um,
Anne I don't know, um..
- Donna what is it, creates a positive.. charge, or something,
or positive, positive energy, or something, or....
I mean a wool rubbed straw makes positive energy?
- Marge If you're saying that the straw is positive, then the
metal has to be negative in order for it to attract.
- Donna Yeah
- Marge But I don't think that.
- Donna Oh
- Marge I don't think the metal is negative.
- Donna Okay

It seems likely that discoveries of differences in thinking like this one came about because the group had to construct a single response, and they felt some obligation (a social classroom norm, see below) to represent ideas that all three group members could accept. Discovery of differences in thinking was supported by the structure of the computer documents and by norms within the small group.

Discovering differences was an important step in constructing ideas. Each group member had to make some sense of what the other was saying. This constituted the beginnings of considering other ideas. In fact, once students found differences, they generally tried to find a response that all group members could agree to. The discussion sometimes changed to "Negotiating a common response from different starting points" below, or some other type of "Extending ideas."

Extending beyond current expressed ideas

These episodes of idea-developing or model-building activity were sometimes incited by differences in thinking of group members. The group members seemed to want a single response. At other times, the computer document asked questions that group members had not considered before. Sometimes individual group members unilaterally suggested new ideas or asked new questions for any number of reasons.

Negotiation of a response from different starting points: When groups discovered differences, they often tried to find a single response that would satisfy all of the different members. This often took some work. Different solutions would emerge: compromise,

adopting one person's idea (perhaps after some coercion), or finding common elements of the different ideas. These discussions often involved significant innovation and often could be considered important times of idea development or "learning."

In the following discussion, the group was considering what would happen when the pieces of a broken, magnetized nail were floated and allowed to turn freely. Marge seemed to believe that they would still orient, but Donna didn't think they would at first. The students were looking at the following diagram:

Imagine that you cut or break a **point-north** nail into two pieces.
Predict what you expect would happen to each piece, if it was then floated by itself. Would it or would it not have a preferred orientation? If so, how **would** it orient itself? Write your prediction below each piece.

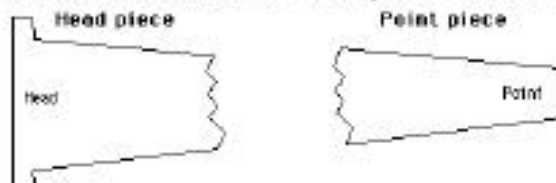


Figure 5-5: Nail pieces question

- Marge The head piece. . . the head of the head piece would point to the South. I think.
- Donna Do you think the whole, well, yeah. Think it would matter? Do you think this might just as well point to the South? Is it all south? You know what I'm saying? Is that whole piece south
- Marge You mean you think it would turn sideways?
- Donna No, I just don't know if it would matter.
- Anne You just think it'll
- Donna I don't know.
- Marge What would it do?
- Donna I don't know.
- Marge I don't either.
- Anne Where
- Donna You know what I was thinking? okay,
- Marge Would, you've got a concentration down here
- Donna This is all norths.. This is all north. What would it do? I'd think it would - do you think it would go that end or that end? Do you think it would matter, to that piece?
- Marge Well, if you dragged it this way the highest concentration of things I would think would be still down at the point of it.
- Donna Ohhh. Maybe..
- Marge And there would be less of them going to this end. And here the highest concentrations of the other ones would be at this end I would think.
- Donna Yeah, okay. That's fair to think that. Okay. Let's just do that. We'll see I guess.
- Marge And we'll see what happens.

This event involved an extension of the idea of magnetizing by separation of charges, that the charges concentrate the most at the ends and are less concentrated nearer the middle of a nail. Thus, this event was a case of "extending ideas".

One thing that happened in the above discussion was that Donna became increasingly convinced that Marge's idea may be useful. However, another thing that happened was that Marge described those details about her separation model for the first time. It is quite likely that Marge had not thought about the relative concentration of north charges at different parts of the north end until shortly before she began talking about it. Thus the negotiation was valuable for the whole group, including Marge. It gave her the opportunity to make her idea about charge concentration explicit.

Constructing an explicit statement from talk: In the process of considering questions, group members sometimes came up with a new idea, or they came to agreement on the general points of a prediction or explanation. However, once they agreed on those general points, they still had to formulate a concise and meaningful statement or diagram, which required further effort. This challenge may be common in many situations. The difficulty of making a step from having ideas to putting them to use was recognized by A. A. Milne (1926). In one of Milne's stories, Winnie the Pooh thought he could whoosh his friend Eeyore out of a stream by dropping rocks in the water nearby. Pooh's plan didn't work out quite the way he had expected, and afterwards he said ". . . when you are a Bear of Very Little Brain and you Think of Things, you find sometimes that a Thing which seemed very Thingish inside you is quite different when it gets out into the open and has other people looking at it."

While this part of Milne's story is about the difference between an idea and its execution, there are similar differences between ideas and their formal descriptions. Once groups in the physics class reached a point of having said things that all three students agreed with, they had the further task of formulating a statement that the rest of the class might understand. Even though the group members felt they agreed on a response, typing it on the screen was not a trivial step, because the words and phrases they had used when coming to agreement were not complete or because the group members felt that some of their casually spoken phrases couldn't be used in a typed description. The group members had to work hard to type meaningful sentences that described their thinking reasonably well.

I will use the following example to show that constructing an explicit statement from talk was a cognitive activity that led to better understanding by members of the group. I will then show how the group used the computer to support this activity.

The group had to construct an explicit statement during the first development activity on Day 2. At one point, the group was asked to explain how they made particular predictions. The group members seemed to have been drawing on prior experience, but they had not explained to each other how they had come to make particular predictions. Donna read the instructions first:

- | | |
|-------|--|
| Donna | "How did you decide? On the top of the next page summarize your thinking. What ideas guided your predictions?" |
| Marge | Woman's intuition |
| Anne | I'm gonna save right now. |

- Donna So, explain, okay. How did we think about it? I kind of picture, wha wou,
- Anne Yeah, that's what I did I imagined in my head
- Donna I imagined,
- Marge I think we made predictions from past experience .
- Anne that's what I was trying to think of things that like
- Donna yeah, you're right
- Anne in my head
- Donna using our past, our previous knowledge,
- Marge Mhmm, previous knowledge
- Donna We imagined, um, performing the event.
- Marge okay. We imagined performing the experiment and we made our predictions from our past experiences. Our collective past experiences.

Notice how, at the beginning, Donna suggested "I kind of picture," as an explanation for how she made predictions. As each student contributed phrases, what they were going to type became more concrete and more in the form of a statement that might be acceptable in a physics class. The students were trying to use what they felt was appropriate language, and the phrase that they eventually came up with was more meaningful than what they said at first.

This particular event also reveals how the group members supported their predictions early in the class. They relied on prior experience. Later, they expressed obligations to use experimental results from class to support their models. This change represented the emergence of a sociophysics norm which is discussed later in this chapter.

Students also used the computer screen to support their attempts to construct explicit statements. Here is an example of how the computer helped groups make their statements more explicit. On Day 4, the students used a computer simulation to compare the pattern of compass needles around a magnet with their own diagram of floating nails around a magnet.

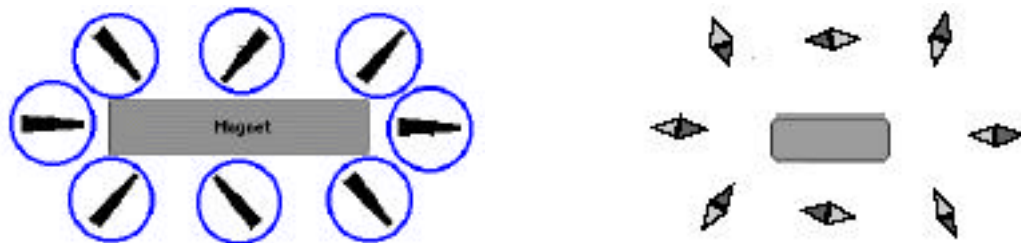


Figure 5-6: Students' observations with floating nails (left) and the simulator picture (right)

The Activity document asked students to compare the two pictures. This was not easy for the video group, and they struggled with words until Donna suggested that Anne

(who was at the keyboard) begin typing some of the things the group members were saying:

- Anne I don't know how to say it exactly - basically we're saying
 Donna you know
 Anne similar with them like their opposites are at one end and - opposite - [laughs!].
 Anne The nails are pointing at one end to the magnet
 Donna um, one, in one side
 Anne and in the other the opposite ends of the nail are pointing toward the magnet. [??] also in our
 Marge Mhmm
 Donna Write - type when you're talking so you don't lose it. That's what I do.

The group members eventually typed a meaningful statement:

"In the picture above, one end of the magnet attracts the light grey point of the nail and the opposite end attracts the dark grey points. This is similar to our experiment, where the pointy ends were attracted to one end of the magnet and the thick ends were attracted to the opposite end of the magnet. The difference between the two is that our middle nails had more reaction to the magnet than the simulator."

This explicit explanation makes meaningful connections between the simulator and the group's experimental results.

When "constructing an explicit statement from talk", the group members used the computer screen as a place to keep their emerging statement while they tried to find a way to formulate the next phrase. They relied on the existing text on the screen to help them formulate the next phrase. Thus their new explicit explanation emerged via an interaction between the three students which relied in important ways on the computer. As the group typist added words to the screen, each group member took those typed words as the starting point for the next phrase.

Extending an idea into a new issue or area: Groups sometimes talked about new issues that had not occurred to them before. This happened when the computer documents raised a new issue, or when a student simply had a new idea, for whatever reason. For instance, one document asked groups to float a magnetized nail on a coffee lid in a tray of water. This sparked discussions about the effects of water on magnetism. Prior to this time, few students or groups had explicitly considered this connection.

Another reason for extending ideas was students' own curiosity. For instance, at one point Donna was watching Anne draw a diagram of a nail. Anne was putting N and S letters at opposite ends of the nail picture. An idea occurred to Donna, and she asked her partners what they thought:

- Donna - - think there's a space in the middle of the nail?

Anne I dunno
 Donna Do you think like the south - they just butt up.
 Anne Just meet at each other.
 Donna You know what I'm saying?
 Anne Yeah
 Marge We didn't test anything for the middle of it, I don't know what happens
 Donna I mean just based on our model, do you think, because we're drawing a picture of what we think's happening, do you think that Ss come right up to the Ns?
 Donna or do you think there's a space in the middle of it?
 Marge I don't know. It'd be interesting to take a magnet and
 Donna Put it in the middle
 Marge yeah, and go up and see when it changes. See if you can keep attraction, attraction, attraction all the way up through the center

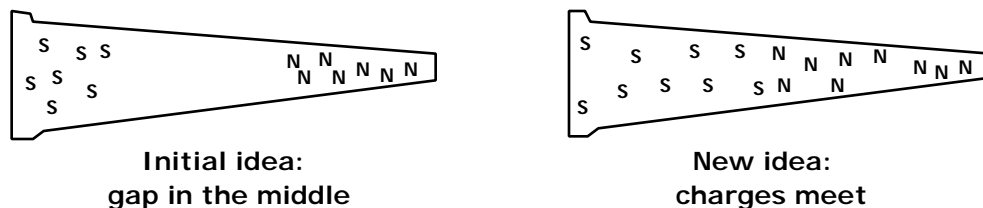


Figure 5-7: Two different charge separation models

The diagram that Anne was drawing on the computer screen had an influence on the group's thinking. Donna asked the question about the gap between N and S while Anne was placing N and S symbols on a diagram of a magnetized nail. It seems likely that Donna's question occurred to her as a result of wondering where Anne should place the N and S symbols. This is another way that the computer screen promoted extensions in students' thinking. Their diagram, which represented their model, raised an issue that they had not previously considered. The students' interaction with their diagram led to examination and refinement of their model.

The "extending ideas" category represents processes of gradual development by students. Whenever the group was extending ideas, new connections were being made that had not existed for those students before.

Interestingly, while the computer documents were carefully designed to give students opportunities to extend their thinking, many of the "extending ideas" events happened spontaneously, that is, they weren't intended by the designers of the course materials, and the designers didn't anticipate those events. The students' own curiosity created idiosyncratic opportunities to extend their ideas, and their use of the computer, particularly in constructing responses or operating the simulators, sometimes sparked questions. Other groups probably often pursued other issues and questions.

Exploring ideas that might be plausible: Sometimes groups considered alternative ideas or explanations. Sometimes a different idea or explanation occurred to one student or another. This category differs from "negotiating a common response from different starting points" in that students may or may not have begun with different ideas, and they did not put their ideas in opposition but simply considered them. There was less initial commitment to the alternative idea. It was also not "extending ideas" because the new idea was an alternative to the group's accepted idea.

In the example shown below, the group was considering what would happen to a floating half of a broken magnetized nail when a second magnetized nail was brought nearby. Donna thought that there were three possibilities - the end under consideration (called "end A") could attract the same as the other end, it could attract less, or not at all.

Donna you think A will, you think A is going to attract also?
 Anne probably
 Marge Although a less effect, I would say a lesser effect.
 Anne you're right. okay.
 Donna Or I guess it could do nothing. Maybe all the forces just pull to the end, and there's nothing in the middle. none of those
 Marge Is that what you think?
 Donna I don't know. No. I don't know. But it's you know, the third alternative. If you took all the forces and the forces just came to the end
 Marge yeah there can be noth-
 Donna and there were none of those forces left, in the middle. and then it could just not react.
 Marge It could not react, or it could react less, or it could, somebody could say well now you've made a polarized, two polarized things.
 Donna yeah yeah I guess there's more
 Marge And you'd have attract and repel
 Donna yeah yeah
 Marge and we'll see
 Donna ohohoh. So which one do you think we should go with?

In the above episode, Donna suggested three possibilities, and Marge thought of a different set of three. Donna was thinking "attract the same, attract less, or no attraction." Then it seemed that Marge may have thought the three possibilities were "attract, no effect, or repel." Because of Marge's different interpretation of what Donna had said, the group had an opportunity to consider a different idea, and a different experimental result.

It seems likely that some (not all, but some) events of exploring alternatives could lead to conceptual changes in small group discussions. After all, to change one's idea, it helps to have another idea to consider. Thus, exploring alternatives was an important type of discussion for the group to have, although it was not very common.

Joint construction of a new idea: On rare occasions, groups whose models were faced with difficulties constructed new models or new pieces of models. The model or idea that emerged was not one that any of the group members talked about before the discussion. This was caused in some cases by unexpected experimental results which caused problems with the preexisting group idea.

No examples of this type of activity were found in videotapes of groups during Cycles I and II. However, in Cycle III, one group developed a substantially new model of static electric phenomena in conductors via joint construction. Because it is beyond the topic of this work, that event will not be described here. This category is included here to provide a more complete list of activity types.

School talk and science talk

Jay Lemke, in describing the culture of science classrooms, suggested the term "science talk" for discussions relating ideas to phenomena (Lemke, 1990). Other researchers discriminated school talk from science talk (Holthuis, 1998). The difference is meaningful here. The first main activity type, "Logistics and following instructions", represents types of school talk. The students talked about doing things the proper way, they decided who would type, or how to draw a picture. These types of activity are not parts of learning physics, but they are necessary to the organization of groups in the class. Group members have to know what to do, and how to do it. These questions are addressed by school talk.

The final two categories, "Comparing ideas within the group," and "Extending beyond the current idea," are types of science talk. While comparing ideas within the group, members contrasted their ideas and sometimes discovered different ways of thinking about magnetism. The "Extending ideas" category represents various types of creative activity in which the group's goal was a better way of thinking and talking about magnetic materials. However, the school talk/science talk distinction is not helpful in the "Checking" category, because group members checked whether they had the proper type of answer as well as whether they had (in their view) the proper concept. The group members wanted to type good answers both because they were interested in understanding and because they wanted good responses for the instructor to read (even though the instructor never graded development documents).

Both types of talk are necessary parts of students' interaction. School talk is important for a number of reasons. For one thing, students want to succeed in their science course. They have to make sure that they satisfy the course requirements, and they have to talk about this. Also, school talk involves such things as figuring out how to follow the directions given by the instructor or in computer documents. This guidance is intended to help students gain appropriate experimental results and to think about issues that are important to developing better understanding of the topic. By following instructions, (assuming the instructions are well designed), students can increase their chances of learning what is intended for them to learn in the course. School talk becomes problematic when students spend so much of their time on it that they miss opportunities to develop deeper understanding via talking about scientific issues.

There were other types of talk in the classroom. For instance, the instructor encouraged the students to get into the habit of trying to understand each others' thinking, because they were going to become teachers, and it would be important to understand their students' thinking. This meta-cognitive or meta-pedagogical talk was neither school talk nor science talk.

Connections to pieces of theories of cognition and learning

Mediation by the computer screen

A cultural artifact is said to mediate cognition when its use significantly changes the cognitive task faced by the system. In order to understand the role of a medium, one must first identify the task. The above activity types represent the types of tasks in which the group engaged while constructing responses.

Discussions involving checking, comparing, and extending were mediated by the representations on the computer screen. Recall from above the example of error correction when Marge corrected Anne's drawing of the group's model of a north pointing nail. Ann began placing Ns at the head and Ss at the point. Marge saw Ann placing charges in the "wrong" ends of the nail, so she intervened.

Ann And do we want all the - okay, south ends
 Marge Want it to be a what?
 Ann south over there.
 Marge North pointing nail.
 Ann So that north's going to be - oh so we want the S-
 Marge want the norths down there,
 Ann Down there. Gotcha.
 Marge exactly.

Because Ann's diagram was clearly visible to Marge on the computer screen, Marge had an opportunity to evaluate Ann's work. In addition, both speakers pointed at the computer screen while talking. Marge used her finger to show that she thought the north charges should go "down there." The computer screen served as a shared space within which the group members developed common ways of representing.

The computer screen served as an "open tool" (Hutchins, 1995, p.270) because all three group members could see it, and they could point to features on it. To make the construction process open, Anne narrated her actions with the N and S symbols so that Marge and Donna could understand what she was doing, and so that they could contribute to the process of constructing the picture. The computer mediated the social process of constructing an acceptable group representation in a physical space.

Another way that the computer mediated discussion was that it compelled group members to construct a single response. This promoted a norm that "the group creates representations that all can agree with." In the face of having to construct a single response, the group members may have felt some obligation to bring their thinking together. This will be discussed below.

CLASSROOM EXPECTATIONS AND OBLIGATIONS (NORMS)

When group members talked to each other and to the instructor, some patterns in their videotaped discussion allowed inferences about students' felt obligations, their expectations for each other, and the instructor's expectations for the students. These inferences are classroom norms. Some of the norms relevant to physics learning involved students' relations with their activity (who did what and how), and science processes (such as relating experiments to models).

Norm types of interest

This research, following Cobb and Yackel's framework for mathematics, organized norms into social classroom norms, sociophysics norms, and physics practices. While all three types of norms may have influenced students' development of ideas, they are not given equal treatment in this dissertation. I describe below one classroom social norm in the small group, and three sociophysics norms.

Classroom social norms

Video of small group and whole class discussions showed evidence of the students' regulating discussions, managing allocation of power, and doing other similar things. One might be able to describe some of these processes in terms of classroom social norms (not sociophysics norms) that reflect important features of the ways students engaged in activities and developed models. The following suggestions were not pursued for substantiation, but are suggestions of possibilities seen in the data. For instance, it appeared that the video group members strove to balance the social influence or power that each group member exerted on the others. This was evident in different ways. Group members took turns operating the keyboard on different days. Also, a group member's social influence was often connected with her suggesting ideas or dictating words to the typist. Perhaps in order that each group member have some power, each group member seemed obliged to contribute to group responses, particularly when the responses were questionable or difficult to produce. When the responses were straightforward and everyone seemed to agree, then group members sometimes only assented saying "mhmm" or "okay." This kind of obligation or small group norm certainly caused certain types of discussion, which most likely influenced the group's model development. It also certainly helped each student to be actively engaged in the group's work, which improved the chances that each student understood the others' thinking.

It appears that some social classroom norms were closely tied to the course structure. Working in collaborative groups required that the group members have ways to get along with each other. Having a single space for a group response required members of the small groups to have a way of determining what was typed or drawn. The instructions given to the students prior to Elicitation activity suggested certain types of actions and speech, which eventually resulted in norms relating to actions in the classroom.

The connection between classroom social norms and model development involves the intermediary of students' activity. Claiming that any classroom social norm influenced groups' development of magnetism models requires showing how a social structure that doesn't directly relate to physics influenced groups' development of physics thinking. Showing this may be hard to do. Because of the less direct relation between social classroom norms and magnetism model development, this dissertation will discuss only

one social classroom norm. This norm, involving how the small group determined whose ideas to represent, seemed to be extremely important to discussions in one small group.

Common Ground: How group members defined what to write in activity documents

Group members were presented with spaces for single responses in the computer documents. There was only one typist per group on a given day, and only one space per question for the group to put a single response. When introducing the course materials, the instructor had suggested that the groups type "their group's responses" in the spaces in the document. This raises the question of what constituted a group's response, or how the groups managed this when there could have been three different ideas (or more!) among the three students. The solution taken by Marge, Donna and Anne can be described by the norm: ***The group was obligated to type responses that were acceptable to all three members.*** The group rarely if ever typed an idea that one member didn't agree with. The shorthand name for this norm will be "the common ground norm." This norm was specific to the small video group. Other groups may have had similar norms, but they were not studied in this research. Also, there were other rules and norms that applied to whole class discussions, so this norm didn't apply to the class as a whole. Rather, it was part of the "small group collective product" described in Chapter 3.

This norm emerged over time as the group worked on Elicitation and Development documents. On Day 1, before Anne joined the group, Donna and Marge each described different ideas about magnetism to each other, but Marge drew her own idea on the group's whiteboard and Donna did not protest. It seemed that the two did not have obligations to put down an idea about magnetism that they could both accept. Then on Day 2, the group sat at their computer and began working on Activity I-D1. When the group was asked to predict which objects a magnet rubbed straw would attract, the members checked whether they all agreed that nothing would happen with any of the objects.

Donna A magnet rubbed straw - - with a paper strip.
 Marge I would say you're going to have zeros all the way across because I don't think a straw can pick up magnetism.
 Anne It's not
 Marge metal
 Anne not metal.
 Marge I don't think you can magnetize a straw with a magnet. You may be able to do it with the wool but I don't think you can with a magnet.
 Marge That would be my prediction.
 Anne I agree, I agree with that.
 Donna Okay, okay.
 Marge Do you agree?
 Anne Yeah, because I, yeah. Cause the only thing I could believe could be magnetized would be like a metal.
 Marge metal. That's what I think.
 Anne So all the way across would be - -

Donna Yeah

In the above exchange, each student explicitly said she agreed with the prediction of no effect. Also, Marge checked whether her group partners agreed. This kind of checking seemed to begin as soon as the group began putting responses on computer documents.

It seems likely that the structure of the group's tasks, as well as things the instructor said, may have given rise to this small group norm. As described under the "checking" activity type, the group had only one space to put answers in computer documents, and the group members wanted to "get along with each other." At the same time, however, the instructor had asked the groups to "put your best group thinking" into their responses. Thus all groups had some reason to come to agreement on what they typed in the documents. Establishing agreement on responses before typing them may also have been a way that the group members balanced power in the group.

This norm seemed to be important in the video group. Only on a few occasions when one group member thought differently than the other two did she keep quiet. Other times when group members disagreed, their disagreements became the foci of discussions. Once when Marge had a different idea from Donna and Anne, Donna typed Marge's idea separately. The bulk of the group's responses, however, were non problematic or the group members compromised by finding statements that they could agree with. It is almost as if they explored what each thought, and typed the intersection of their beliefs (see figure below).

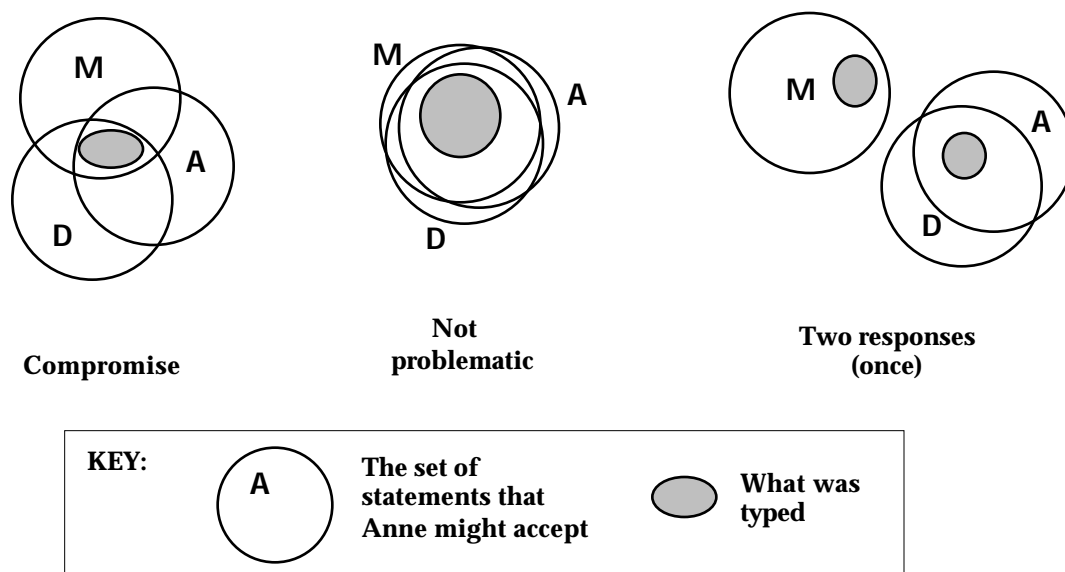


Figure 5-8: Types of students' compromises

In the above diagrams, each circle represents "what each student might have accepted in a written statement." The hatched regions represent "the response the group decided to type." The group typed two different responses only one time.

The times when group members had to compromise, however, made this norm more apparent. "Making statements that were acceptable to all members of the group"

became very important during Activity I-D2 when Donna and Anne changed their thinking from "one type of charge" to "separation of charges." This change, and the influence of this small group social norm, are detailed in the section on "connections to development of models" later in this chapter.

The major feature of norms is that they are interactively constituted. Thus as the group's tasks or understandings changed, one would expect the norms to gradually change as well. The description of this norm, however, is intended to cover what happened in the group over a period of four weeks. At the beginning of the course, the students seemed to be concerned that each member "agreed" with the response on the screen. As time went on, the group members were developing models of magnetism against which they could check for agreement. Thus some of the group members' concerns might have shifted from agreement (or not) on the typed descriptions to agreement (or not) on models. However, when the group members found differences, their efforts in typing still centered around constructing compromise statements to which they could all agree.

Sociophysics norms

Sociophysics norms represent aspects of the culture of physics as they are enacted in the classroom. The sociophysics norms in this class were related to the physics content of the course and to the science values promoted by the instructor and the students. Of course, these norms were constituted in cycles of interaction and sometimes negotiation as the students responded to content issues or the instructor's statements. In this classroom, three prominent norms involving descriptions, evidence, and models emerged during the first eight days of the course. These norms involved how students were obligated to generalize descriptions of phenomena (to be called the generalization norm,) how the entire class determined the acceptability of evidence (the evidence norm,) and how the group members justified their models in public discussions (the models norm.) These are described in turn below.

Generalization: How students described magnetic and static electric phenomena

At the beginning of the course, students were asked to describe what they thought happened with refrigerator magnets that made them stick to refrigerators. As seen in Chapter 4, many students described charges as causing the attraction. Thus, from the very beginning, students used language involving charges to talk about magnetic and electric phenomena. They sometimes combined general descriptions of phenomena with explanations of what caused those phenomena. The instructor wanted the students to separate their observations and "evidence" from their ideas or models of magnetism. Over time, the class developed a norm involving a separation of models from generalizations of phenomena: ***When publicly describing general features of magnetic and electric phenomena, students were obliged to write or speak in terms of observables only, without reference to charges.*** Here, "publicly" means statements in whole class discussions or typing in computer Activity documents. This obligation was not present at the beginning of the course. The evidence available from video suggests that this norm describes obligations within the small group as well as within the whole class. However, private discussions within the video group were not always subject to the same norm - it was more evident when the group was formulating public statements.

In the following paragraphs I will claim that students' initial use of the model language of charges in describing phenomena may initially have been useful to their development of understanding. Then I will show how the separation of models from evidence in the class emerged and became constituted as a sociophysics norm.

When studying new and as-yet-not understood phenomena within their scientific field, one of the challenges scientists face is that of producing cogent and succinct descriptions of the phenomena of interest. Scientists may, like students, have some initial ideas of what is going on, and like students, scientists may try to make sense of new phenomena in terms of models and ideas that they think apply. As a result of accumulating experience and developing senses of the phenomena, students and scientists may gradually identify salient features of the phenomena of interest, and in conversations with peers, they develop Garfinkel's "reciprocity of perspectives" (Heritage, 1984) with respect to the phenomena. They eventually can talk about events of interest without necessarily invoking connections with models.

Recognizing the importance of reciprocity of perspectives in discussions is a key to understanding the possible value of mixing descriptions of phenomena with models. Recall from Chapter II what this is. Heritage described Garfinkel's reciprocity of perspectives as that sense of the situation and those referents that are taken as shared by participants in a conversation. A reciprocity of perspectives allows participants in a conversation to infer vast amounts of contextual information that they or their partner couldn't state directly. Having a reciprocity of perspectives solves two related problems for scientists and students in new situations. It makes it possible for people to identify the salient features of the phenomena, and it supports conversations about the phenomena. When beginning their investigations, members of either group may not be able to talk about the phenomena in similar ways because they may not be looking at the same features and they may not have the same ways of talking about what they are seeing. Using a preexisting shared set of terms like "positive and negative charges" in connection with "opposites attract and likes repel" may provide students with ways to carve out relevant aspects of the phenomena and to describe phenomena briefly in ways that convey their sense of the situation. The students use the language of charges to organize their use of language. This is the reason that students may benefit, at least at first, from mixing up models with descriptions of phenomena.

However, students in science classes eventually benefit from explicitly separating their descriptions of phenomena from their guesses about what causes that phenomena. This can allow students to change their theoretical models without having to change what they observe happening. One objective of this course, in fact, was for students to develop more sophisticated understandings of scientific processes, including the relationships between evidence and models. Thus, the instructor was alert to students' use of words about charge when they were used to describe phenomena.

Here is what happened. Students seemed to talk about phenomena in terms of charges fairly freely until Day 4 when the groups were to present their candidate ideas for Cycle I. These candidate ideas were to be each group's best thinking about similarities and differences between static electricity and magnetism, and they were to include generalizations of phenomena, but with no mention of charges. The instructor did not want groups to propose models of magnetism yet; that was for Cycle II. He may have been concerned that if students proposed ideas about charges in Cycle I, those would carry into

later cycles in the unit and make it more difficult for students to change their thinking towards the target ideas.

The instructor's initial statements about distinguishing observations from models came in a discussion on Day 4. He had been showing the entire class a set of magnetized nails, some of which pointed North and others which pointed South when floated in a tray of water. (This was the class period after groups had done similar experiments in Activity I-D3). The instructor's purpose was to alert students to the differences in orientation of the nails, and to raise questions about how different kinds of nail rubbing might have caused those differences. Some students seemed to notice that he used different ends of the magnet in rubbing. Then Donna raised her hand, and suggested that rubbing with the magnet separated charges (or "ions") inside the nails:

- Donna Our group has an observation about why we think every other one is pointing the other way.
- Inst. You have an observation?
- Donna We have a - what can you say?
- Marge A prediction?
- Donna Well, we think we know why - a possibility why the pointed ends, every other one is pointing the opposite way. [??? one whole sentence is inaudible]
- Inst. Okay
- Donna When you rub the magnet onto the nail you bring the negative ions to one end, so every other one is going to come the opposite way because the positive is going to be attracted to the negative on each end of the nail, and that's why every other nail is opposite to each other.
- Inst. So you representing your group are presenting what you think , Donna, you're describing, representing your group, what you think might be happening inside the nail
- Donna inside the nail
- Inst. to give rise to this observation that there are some differences here.
- Donna Yeah
- Inst. So you're making use of what you think is going on inside the nail. So that we call a model. You're making an inference, okay? Did you observe these things you call positive negative ions actually moving? Did you see that happen?
- Donna No
- Inst. So what you were describing was not an observation.
- Donna No, it wasn't.
- Inst. It was a model your group was trying to use to make sense and explain this. And in science, that's ultimately where we have to go. It's really really important. So you've provided a possible model to explain it. Which we all want to do. It's really important.

- Inst. Now, what I want to encourage your group and the rest of the groups that it's fine to write down these models right now, for what you think is happening. But I want to sort of as a class hold off detailed discussion because there may be a lot of other models that other people may have for what's going on. We want to hold that off to cycle II, which will be next week. That whole cycle will be focusing on building that model that you've just suggested here, which is a great thing to do. Okay?
- Inst. But before you build a model, you have to be really careful on the observations that you're going to build it on, cause you're going to try to explain something. So today, when you put together your final ideas that you want to suggest to the class, as candidates, I'm going to ask you to try to make your ideas be general statements about what you observed happening; and statements in which are trying to explain it, like for example you did, if you could hold them but hold off suggesting them to the class for Cycle I, those are the things we want to do for Cycle II and Cycle III

Hopefully it is clear that the instructor emphasized the importance of having ideas about "what was going on inside the nail." However, he also asked the groups to not suggest those kinds of ideas in the first Cycle. The students interpreted this statement a little differently from what the instructor may have intended. In their small group immediately after the above whole class event, Donna, Marge, and Anne compared the simulator's presentation of compasses around a magnet with their own diagram they had made the day before. They were looking at their diagram of nails floating around a bar magnet (see Figure 5-6).

The students were trying to find a way to describe the two patterns. One of their concerns was in identifying which ends of the simulated compass needles corresponded to which end of the magnetized nails. They eventually figured out that they couldn't tell. The following discussion, which could be categorized as "constructing a concrete statement from talk" also contained some negotiation of the group's sense of the instructor's statements about models and observations:

- Marge . . . I think the thing that is making sense here is one end is attracting the pointy ends and the other end is attracting the thick ends and that's what happened to ours too.
- Anne Yeah
- Marge the fact that ours is in an opposite position is irrelevant. Because this magnet could be turned in the opposite position.
- Marge If what we're thinking is true, there's a positive end and a negative end of a magnet.
- Donna But
- Marge But our little middle ones had a reaction.
- Donna But all we can do is make a comment about the observation - no guess work.
- Marge Okay
- Donna so we can truly say what you said which is one end is um-

Marge yeah you're right
 Donna one end, the grays point at one end, and the dark, how do we say that?
 Anne Um
 Donna you know what I'm saying?
 Anne Yeah. That the pointy end - what did you say? We can't say
 Donna We - are - some
 Marge We can't say why we think it is happening we can only observe what's happening
 Donna We can only say what we see. So, can we say
 Marge that in our experiment, our, um, thick ends pointed toward the right end of the magnet
 Donna Uhuh

Notice how Donna suggested "no guesswork" and later she said "what we can truly say". It is as if she were attempting to apply ideas relating to integrity or honesty. Marge, however, said "we can't say why we think it is happening, we can only observe what's happening," which seems to be based on a sense of what is allowed or not allowed. Overall, the group members were attempting to make sense of what they had heard the teacher say.

The group's initial interpretations were refined later in the class period when the group was working on Activity I-D4. The experiments involved testing what happened when a wool-rubbed straw was held near a wool rubbed plastic stirrer in the test stand. The purpose of this activity was to elicit students' ideas about two rubbed objects, and for students to have their first experience with electrostatic repulsion of like-rubbed objects. The students were making predictions per the instructions, and they talked about what was required in their typed prediction.

Donna [reading the document] ". . . predict what would happen to the rubbed test stirrer. Would it be attracted?"
 Anne [???)
 Donna "Would it be repelled by it?"
 Anne I think it will be attracted to it.
 Marge I think it will be attracted to it.
 Anne Are we not supposed to [?] we are not supposed to go into detail though.
 Marge No, we're not. But it says how did you decide.
 Anne Donna, [laughs]
 Donna I don't know.

Anne's contribution to the group's constitution of the emerging norm was to suggest "we are not supposed to go into detail." There were more things going on in this group. Anne appeared to be ribbing Donna for her apparently unsuccessful suggestion

about ion separation in the whole class. Perhaps the group members interpreted the instructor's request to not formally propose magnetism models yet as injunctions to not talk about models at all. They seemed to think it was a preposterous requirement, and Marge and Anne made jokes about this particular obligation. For example, when doing experiments, on the same day, Anne noticed a pattern in the action of rubbed objects. She noticed that after a pair of plastic objects were rubbed together, one of the objects attracted a rubbed stirrer and the other one repelled the rubbed stirrer. This is exactly the kind of observation that the instructor hoped the students would make. However, Anne added a joke after her observation, and Marge took Anne's joke farther:

Donna	Okay, here's my garbage bag.
Anne	ooh
Marge	Repelling
Anne	It seems like that one attracts and any object that's rubbed with it is repelling. Actually I shouldn't make such an observation. Sorry.
Marge	[laughs] We're just dumb children here! Don't be thinking!
Anne	Thinking.
Marge	Caught you thinking!

During the rest of the class period, Marge, Donna, and Anne didn't talk seriously about charges involved with the static electric effects. Thus, initially, the small group seemed to feel an unwanted obligation to not talk about charges at all. Only later in the unit did the group members begin to differentiate between descriptions made to each other, when they may have felt they could talk about charges, and generalized descriptions of phenomena made on computer documents or in whole class discussions.

The group's early frustration with their interpretation of the instructor's statement is understandable. Anne said that her group's model was helpful to her, as I suggested above. I had been interviewing the students in the video group weekly. Trying not to influence either the group members' thinking about magnetism or their relationships with each other, I mostly asked them what their thinking was, and how they felt about things that happened in class. My goal was to obtain more information for triangulation. In an interview two days after the above discussions took place, Anne described her group's separation model and then admitted that she knew she "wasn't supposed to be making models already. . ." But then she said "But this is my idea I have now and it's kind of - it makes me understand magnets."

The development of this norm progressed through what seemed to be a series of student interpretations. The range of statements which suggest the video group's interpretations included Donna's "no guesswork" and "what we can truly say," Anne's "we are not supposed to go into detail," and Marge's "we can't say why we think it is happening, we can only observe what's happening," and "Don't think! Caught you thinking!" The group members may have been expressing frustration, but their descriptions of electric and magnetic phenomena changed. The group members struggled to create language that described what they saw without referring to charges.

This issue came up on Day 5 in the whole class discussion of Candidate Ideas for the first cycle. Bob said that ". . . we rubbed both nails, there was a magnetic charge that was on both nails and depending on what end you brought it to there was an attraction or a repulsion of the two nails." Other students began talking about "charges" or "forces." The instructor intervened, saying "Let's look at the word rubbed and the word charged. The word 'rubbed' is an act that you observed. What about the word 'charged?'" After this a few students mentioned charge, but only when describing rubbing. Most of the discussion that followed on that day did not use the word "charge."

The students' interpretation that they were not to be formulating models ended at the beginning of Cycle II when groups were explicitly asked to describe their thinking of what happens to a nail when it is magnetized. Donna and Marge talked about this during the Cycle II Elicitation discussion:

- Donna So, um, This is "what do you think?" Therefore can we sort of create this model of what's happening?
- Marge This is model creation time.
- Donna Cool!
- Marge [laughs!]
- Donna So we can use our hard evidence, observation, meaning the facts that magnetism has a directional pull, you know, these things that we as a class have agreed with.
- Marge We can do that and we can also describe our observations.
- Donna And it was confirmed by Dr. Goldberg that two sides of a magnetic object hav- behave differently. We know that by observation, positive- you know, attracting and repulsion, right?
- Marge Mhmm
- Donna So based on those things we've observed we therefore make the model at the ends you know, we're thinking that opposites, do the pulling, you know.

At this point, Donna, Marge and Anne again began talking about charges in magnets. But notice how Donna continued to check herself. She may have intended to say that "have different charges" but she changed it to "two sides of a magnetic object behave differently." She may have intended at first to say something like "positive charges attract negative and repel other positives" but she changed it to "attracting and repulsion" and said "opposites do the attracting." One feature of Donna's descriptions, and of other students as well, was that she began saying what happened with objects independently of saying that the charges made it happen. Thus the description of this norm, that students were obligated to generalize descriptions of phenomena in terms of observables only, applies to the later stages of the course after students again felt as if they could talk about charges, now in terms of their models.

The above transcript shows Donna beginning to talk about phenomena and "hard facts" separately from her group's model. This norm about generalized descriptions was part of the emergence in the classroom of distinctions between models and evidence. The issue for students of separating "what they observed" from "what they thought explained

it" also entered into their construction of models. As time went on, groups made fewer claims that they could not support. In Cycle II, for instance, Marge and Donna were careful to not specifically claim that there were + and - charges inside nails because they felt they "didn't know yet" what was inside the nail.

The question of what kinds of observations could be used to support models came up in the Consensus discussion on Day 5. This discussion and ensuing ones led to another whole - class sociophysics norm, which is described below.

Evidence: How the whole class determined which evidence to allow

Students enter physics classes with a wealth of experience. The students in this course had the opportunity to apply some of their experiences to questions about magnetism. However, not all students shared the same set of experiences or interpretations of common experiences. Because of this, the class needed a way to determine which experiences or observations would be acceptable as evidence. In the Cycle I Consensus discussion, a few students protested when another student claim that magnetism is not effected by water. They had not explicitly done an experiment to test that. Later in the same discussion, students also protested another student's claim that magnetism lasted a very long time because he had seen refrigerator magnets stuck to the fridge for years. Again, the protesters argued that since they had not done that experiment in class, they could not have the permanence of magnetism as a Class Idea. The instructor backed both protests. As a result of these and later discussions, ***students in the class were obligated only to admit evidence that was obtained from experiments conducted in the class.*** The way to support claims in whole class discussions was to refer to relevant experimental results that had been done in the class. When students or groups supported claims using experiences from outside the classroom, these were challenged by other students or by the instructor, and claims based only on experience outside the classroom were not accepted.

This norm characterizes the whole class discussions and not the discussions within the video group, which were much less formal. That is, it is part of the "whole class collective product" (described in Chapter 3) but not part of the "small group collective product." Of course, this obligation affected small group discussions, because the small group members sometimes had to support models in whole class discussions.

As will be illustrated below, this norm emerged in the consensus discussion for Cycle I. Some groups had suggested that one of the differences between static electricity and magnetism was that magnets lasted longer than static electricity. The instructor asked how any other students felt about this idea. Diane said she didn't think it could be supported, because her group (and others) had not specifically investigated that particular phenomenon.

- | | |
|------------|--|
| Instructor | Is there a difference in terms of short-lived or long lived? Do magnetic objects seem to be as short lived as electric objects based on our experiments? |
| Diane | Well, we didn't watch static electricity to see how long it would last. |
| Instructor | Okay so the question is do we have enough evidence to make a statement at all here. |

- Diane No
- Unknown Student No, we didn't note the duration, we just wanted to see if there was an effect.
- Diane We just moved on to the next one. We didn't care how long it lasts.
- Instructor Okay, class, so the question here is, because some people didn't put a statement down here - - only if we feel comfortable should we have it as a main idea. If we can't we can put it aside as a possibility but not as a main idea.

More discussion ensued. Some students claimed that they had observed the static wearing off but not the magnetism, but Diane reiterated, "We can't prove it because our experiments were not to do that." The instructor said "let's try to go with statements that we can support with some kind of evidence, and look, it could be that we may not be ready to make a definitive statement as an idea." Some students seemed to think that there was enough evidence to support a statement about different lifetimes of static electricity and magnetism, but Julie sided with Diane: "I think she's right that wasn't part of our testing that we didn't really - can't really make a statement about that because we don't know how long the static really lasted or the magnetic-charges really lasted." In the end, the instructor typed the idea that static electricity does not last as long as magnetism, but he labeled it as tentative and needing more evidence.

This obligation to refer to experiments done in class continued to be negotiated. Later on in the same discussion, Susan proposed another idea for the whole class to consider as a consensus statement. She wanted to have something written about how floating magnetized nails oriented North and South. The way she justified this idea indicates she was aware of the issue of having had evidence in the classroom experiments:

- Susan Can we say something about magnetism has something to do with direction - it had a directional pull? Cause that's totally different, we haven't put it up there, and it's significant. I think, because, you never saw anything like that in the static electricity. But then we did the whole experiment on the magnet and which way it would float when you put it in the water. And obviously there was a certain natural direction that it tended to.

Susan carefully clarified three things. She said that her directional pull idea was different from the other ideas so far accepted by the class, that the phenomenon was significant, and that the class had done a whole experiment on how nails would point certain ways. Susan's proposal was accepted by the class and by the instructor, and made into a main idea.

Models: How students justified or changed their models

During Cycle II in which modeling was expected, groups justified their models of magnetized and unmagnetized nails by referring to evidence. ***Students and groups were obligated to have models that they could support with specific evidence that was acceptable to the class.*** (What comprised acceptable evidence

has been described in preceding pages). In this class, supporting a model required referring to experimental results or the Class Main Ideas from Cycle I.

The class's obligation to support models with evidence led students to modify their group models when they encountered experimental results or recalled experiences that their model could not account for. Groups were expected to have models they could publicly support.

One of the times the instructor promoted supporting models with evidence was at the beginning of the Elicitation activity for Cycle II. He asked students to compare their individual drawings of unmagnetized and magnetized nails, and then he said:

Instructor Also, what evidence do you have that would support the model? In other words, did you make it up out of the clear blue sky? Or did you invent it based on some observations you did in Cycle I, and your model seems to go with those observations? That's the kind of evidence we'd like to bring to bear and come up with a model.

This was only one of many occasions when the instructor brought up the relation between evidence and model. The groups seemed to accept the obligation to make those connections in their presentations, in fact, the video group discussed this explicitly, as is shown below. At the time of the discussion shown below, Donna and Marge agreed on a separation model, so what they would draw was not at issue. Their discussion focused instead on the new expectation that they should make a group model, and how they would support their model. (This transcript was also used to illustrate the group's evolving sense of how to make generalizations, but it is repeated below to illustrate the group's evolving sense of the relations between models and evidence.)

Donna So, um, This is "what do you think?" Therefore can we sort of create this model of what's happening?

Marge This is model creation time..

Donna Cool.

Marge [laughs!]

Donna So we can use our hard evidence, observation, meaning the facts that magnetism has a directional pull, you know, these things that we as a class have agreed with.

Marge We can do that and we can also describe our observations

Donna And it was confirmed by our instructor that two sides of a magnetic object hav- behave differently. We know that by observation, positive- you know, attracting and repulsion, right?

Marge Mhmm

Donna So based on those things we've observed we therefore make the model at the ends you know, we're thinking that opposites, do the pulling, you know.

Donna If you put it - the north, north end down it's going to drag those south, whatever they are,

Marge Mhmm

Notice that Donna appeared to be concerned about the kind of evidence that would be acceptable - she used the terms "hard evidence, observation" and referred to an observation that was "confirmed by the instructor." This is more (of my) evidence for a norm about what (physics) evidence was acceptable in the class. This norm, which I claimed was primarily a whole class norm, was important in the small group because Donna was concerned with how her group would represent their model to the whole class.

The group's sense of obligation to have a model they can support with experimental evidence was also apparent in their discussion of possible evidence, and in Donna's statement "So based on those things we've observed we therefore make the model. . . ."

A few minutes later, Marge stopped the circulating instructor to clarify the group's task. Their instructions were to draw a model diagram on a whiteboard, and then summarize their supporting evidence below the diagram. The following interchange seems to be an example of direct negotiation between instructor and students of expectations and obligations in presenting and supporting a model:

Marge Um - Dr.? We have our picture. Now down here on explanation do you want us to write why we decided that this is what we think is happening inside the nail? Like we observed -

Instructor Yes. So you have to have some kind of evidence from the first cycle that you have gone on to lead you to make this type of a drawing

Donna Oh oh oh oh

Instructor So you just kind of summarize in a few statements here you don't have to write in long sentences, but just summarize the main reasons or the evidence that you are drawing on. um,

Marge So we talk about our experiments and what we saw?

Instructor you could-

Donna We can't think of a mo-, we can't say a model, though right, but say we just, decide on evidence we have come up with as class consensus

Instructor Okay

Donna For example magnetism has a directional pull.

Instructor okay

Donna We can use that hard, well, sort of fact, I don't know if I would say fact

Instructor okay

Donna To help us think why it's -- is that fair [??]

- Instructor That seems to be - - right. So that this is kind of an invisible model of what you think is going on inside the nail. You don't actually see these things happening, you only see the solid nail. So what you're doing is, you know how it behaves, and you're using that behavior that you discovered in class to come up with a possible model that would give that result that you saw, which is what you're representing here.
- Donna okay
- Instructor And so these pictures in a sense comprise your model. And down here just a few statements about the evidence or the reasons why you think this is a particularly good model.
- Donna okay
- Instructor and that's what we're asking each of the groups to do, and it'll be interesting to see the various ways, the various models that groups come up with at this point. Okay?
- Donna okay

When Marge first flagged the instructor, she suggested that the group could write "Why we decided that this is what is happening..." The instructor responded with "you have to have some kind of evidence." After that, Donna seemed to be trying to clarify what constituted valid evidence. Her use of the phrase "hard facts" supports this interpretation. Part of Donna's concerns seemed to involve making a clear difference between writing a model description and supporting it instead with evidence. That might be why she said "we can't say a model, though, right?" She was referring to the task of describing her group's supporting evidence.

This event seems to exemplify the inextricable connectedness of social and cognitive processes. Marge and Donna seemed to be concerned with understanding their obligation to make an appropriate presentation to the class and the instructor. This is a social issue. At the same time, Donna and Marge were developing ways of thinking and talking about evidence and model, which represent cognitive processes.

Later discussions in the small group often connected the group's model with evidence. The group's discussion shown under "Extending into a new issue or area" is an example of this (see above). Donna was thinking about how separated the charges were in a magnetized nail. She asked "Think there's a space in the middle of the nail? Do you think like the South - they just butt up?" The response accepted in the group was to do an experiment. Donna spent some time moving the point of a second magnetized nail along the side of a floating magnetized nail. She was trying to see where along the floating nail the attraction ended and the repulsion began. The group immediately referred a theoretical issue to experiment.

This norm for supporting models with valid evidence does not completely explain the circumstances involved when groups changed their models. Prior knowledge, existence of alignment models in the class, and individual values and beliefs are all circumstances that probably influenced groups.

Prior knowledge made a difference in what groups did. Some students seemed to know before breaking a magnetized nail that the two pieces would still be two ended. As

soon as they were asked to predict the behavior of nail pieces, three groups switched to alignment models.

Because two groups had presented diagrams of alignment models during the Cycle II Elicitation, the other eight groups in the class didn't have to invent the idea of alignment, they could just use other groups' models they had seen. However, some students had concerns about the propriety of appropriating models that had been suggested by other groups. In fact, at the end of Cycle II, Donna confided to the instructor that she had hesitated to switch to an alignment model because other groups had presented it already. Alignment wasn't "her idea" so she didn't use it until after Day 7. Donna's possible concern for academic integrity or personal ownership of ideas did not seem to be obviously connected with a norm in this class, however. Rather, it seemed to be a personal value that she developed before entering the class, and which other students may or may not have shared.

However, the norms that evolved in the class, particularly those described above, were part of groups' development of models. This hopefully has been made clear. The following section will detail two changes made in Marge, Donna, and Anne's group, and show connections to both norms and patterns of response construction activity.

CONNECTIONS TO DEVELOPMENT OF MODELS

When I began working on this dissertation, I had the goal of identifying significant connections between social and cognitive processes. Research question 2c represents this goal. In the process of writing this chapter, however, it has become increasingly clear that cognition and social processes seemed to be inextricably linked in the activity I studied. Many of the examples of norms and activity types in this chapter provide evidence for the connections I wanted to understand. Discovering those details came about as a result of studying each episode in detail. This might be a common phenomenon. It may be that if one wants to say that cognition is constituted in social processes, supporting that claim may have to be done by examples.

This section was initially intended to make those connections that now should seem somewhat apparent. However, all of the analyses were done from the standpoint of trying to understand patterns of activity and social norms. This section can make an additional contribution by examining two stories of model changes made within the video group, and identifying norms and activity types in the group interactions.

Students in the video group made major changes in their thinking in two episodes that were captured on video. These two episodes are the topic of the following analysis. The second change happened before and on Day 8 when first Donna and Marge, and then Anne changed from their separation model to an alignment model. The first change took place on Day 3 when Donna and Anne changed from using a "one charge on each" model to a separation model.

Change from "One Charge On Each" to "Separation of Charges"

During the Elicitation Activity on Day 1, all the groups were asked to describe what they thought was happening when a magnet stuck to a refrigerator. (For more details on this Activity, see Chapter 3 or Appendix 1). From the very beginning, Marge talked about two kinds of charges on the two ends of magnets. Her model was consistent with the

separation of charges model type. (She didn't actually think of the process of physically separating charges inside a nail, however, until Day 3. Instead she seemed to just think that the two ends of magnets were opposite). Donna, on the other hand, drew on Day 1 a "one charge on each" type of diagram. After some discussion, Marge drew a separation type diagram on the group whiteboard. Anne was not in the group on Day 1.

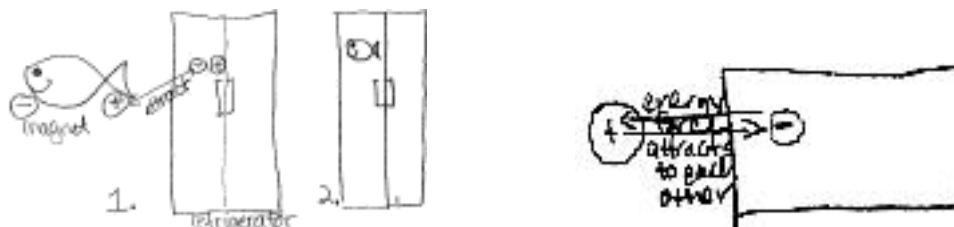


Figure 5-9: Marge's and Donna's refrigerator diagrams

In the above pictures, Marge drew + and - signs on opposite ends of the fish magnet on the left, while Donna drew a + on the round magnet. Donna and Marge didn't apparently try to reconcile their differences on Day 1. Anne joined the group on Day 2. Her thinking on Day 1 is not clear from her drawing. But during discussions on Day 2 and the first part of Day 3, she seemed to favor Donna's model. During discussions on Day 3, both Donna and Anne changed how they talked about nails and magnets. They began to use the separation model, and applied it consistently for a number of days thereafter. This change is diagrammed below. The oval represents the time when Donna and Anne began talking and writing about separation models. The diagram below is not intended to convey "conceptual change" in the traditional sense of the term, because it not clear that Donna or Anne had unitary conceptions in their heads. In fact, Anne drew a different kind of model on a later homework assignment. So the diagram below represents the model type that students expressed in conversations with each other).

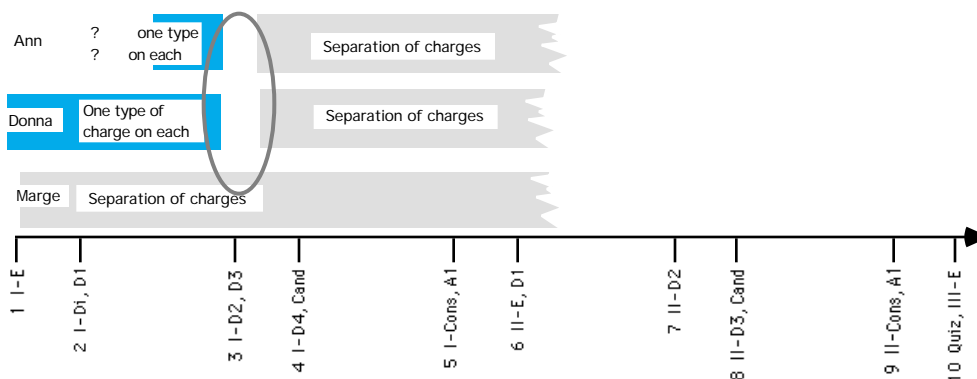


Figure 5-10: First model change within the small group

The "one charge on each" model does explain why magnets stick to refrigerators, (because opposites attract) and the special status of positive charge as used in this model allows students to think that the magnet is what causes the attraction, while the refrigerator on its own would not cause attraction. One of the major problems with this model, on the other hand, is that if one thinks that "like charges repel" then two refrigerators that are both negative would repel each other, and this is something we don't see in everyday life.

Donna encountered that problem on Day 3, as the group was working on Activity I-D2. The group was asked to predict what an unrubbed nail would do when held next to a

series of types of wires placed in the test stand. All three students agreed that nothing should happen because the nail wasn't rubbed yet. However, Donna discovered the "two negatives" problem with her model at this point.

- Donna Okay, "Imagine if you placed each of the six wires and brought first an unrubbed nail.." So an unrubbed nail, to-.. metal and metal ooh. You know what...
- Anne I don't think it'll do anything
- Marge I don't think so. I don't think it should.
- Anne But it did that, like in one of our observations was with an unrubbed nail attracted a paper clip and we were surprised by that.
- Marge Um hmm.
- Donna But if we were consistent, see, we thought that, .. metal is negative, and there's another negative.
- Anne (unclear) yeah. It shouldn't.
- Donna Oh but it's not ch.. but would it be repelling?
- Anne uhuh

It seems that at this time, Donna was figuring out that her model predicted that two unrubbed pieces of metal would repel. Maybe Anne realized this too, when she said "uhuh." This discussion was part of a response construction episode, because the group had read the question and was preparing to make a response.

The group's discussion after this point was involved and lengthy. They talked about both static electricity and magnetism. The main points to be considered here will be how Marge was prompted to explain her separation idea in detail; how the group tried to compromise; and how Donna finally accepted the separation model. Anne changed to Marge's separation model quickly, as will be seen.

After the discussion above, Donna and Anne attempted to resolve the problem of two negatives repelling by distinguishing between the term "negative" and "charged." Donna said that the unrubbed wires that she called negative were not charged. Marge apparently thought differently, but did not say anything. Then the group moved on to discuss what would happen when a magnetized nail was held near each unmagnetized piece of metal. All the group members agreed that there would be attractions. But then Donna also offered a reason why she thought the nail would attract wires. She said "I think that a magnet is positive." At this point, Marge offered her idea about two ended magnets, with a new explanation of how they got that way.

- Donna I think a magnet is positive.
- Marge My remembrance of magnets is that they have a positive end and a negative end, and that the reason they are called magnets is because something has been done to them to move all the negative ions to one end and all the positive ions to the other end.
- Donna Yeah, on one side... and one to the other side. It's not.. mixed all together.
- Marge Yeah. Right.

- Donna So
- Marge And that all these metals have all the same - - capacity in them but they have not had the ions moved from one end to the other. So unrubbed things are just going to be plain together, but if you rub it, and that's why they say to just rub it one direction, that it's pulling... whatever. If this is the positive end of it, it's pulling all the positives down to that end.
- Anne Ooh!
- Donna Yeah
- Marge And pulling and pulling and so you're making it a bipolar - - thing where you're going to have a positive end and a negative end.
- Anne Uhuh, okay, I see what you're saying.

The preceding discussion could be categorized as "discovering differences" because Donna and Marge described their two different ideas about magnets. It was also the beginning of Anne's change to accepting a separation model ("Ooh!") and Donna's as well, although Donna's change was apparently much more difficult and probably much deeper at first.

Why did both Donna and Marge talk about charges so much? Perhaps they felt obligated to make sense of the experiments they were doing, and they had already done so using charges on Day 1. I have shown above how the instructor tried to help students distinguish models from generalizations, which ultimately resulted in the class developing the generalizations norm. But that started on Day 4, and on Day 3, members of the video group seemed to feel free to talk about charges. This is apparent in the above transcript. Specifically describing their thinking about what charges might be doing in nails was important to the group's moving to a separation model. Were the group members socially obligated to connect models with predictions? The models norm had not yet been constituted in the class. But this early in the course, students may have already felt some obligation to connect their thinking about phenomena with ideas about charges. This may have been a precursor to what eventually became the models norm. At this time, Donna and Marge spoke as though thinking about charges was part of their tasks. It is at least plausible that Marge's and Donna's senses of obligation played roles in promoting the group's discovery and comparison of differences in thinking.

In a discussion on Day 3, Marge explained how she thought the charges would move to one end of a nail as a result of rubbing with a magnet. She then explained how a magnetized nail could attract an unmagnetized piece of metal wire.

- Marge . . . So if we put that [magnet] on the nail and we rub it this direction, we're dragging all the positive ions down to that end.
- Donna umhmm
- Marge So then when you go over [to an unmagnetized wire] you've got a piece of metal that has all the ions all mixed up.
- Marge They aren't at one end or the other. But the positive is going to be attracting the negative ones on that.
- Anne Oh!

- Marge It's going to be pulling them toward it. And this [the nail point] is going to have a higher concentration of positive
- Donna Positive
- Marge than negative so it will be attracting the negatives over.
- Anne I like the way you said that, that's good. That makes sense to me.

When she said the positive end of a magnet would attract the negative charges in an unrubbed object, Marge ignored the effect on the positive charges that were also there. The diagram below summarizes what Marge described to Anne and Donna.

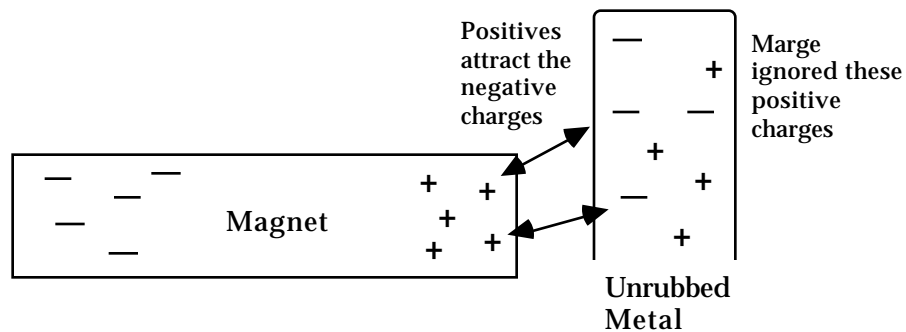


Figure 5-11: How Marge thought a magnet attracted unrubbed metal

Anne apparently liked Marge's idea. She said "See now that makes really good sense to me." From what she said in the rest of the discussion, Anne appeared to use Marge's idea. She did not take time to carefully examine Marge's separation model before saying she liked it. Donna, on the other hand, had difficulties accepting the idea of positive and negative charges inhabiting metals all the time, even before they were rubbed. She was thinking of charges differently than the accepted physics notion of charges as objects with mass and extent, that obey conservation principles, and so on. Donna may have been thinking of charge as something more like a condition of an object, which could increase or decrease or be nonexistent. To change to thinking of metals as containing two kinds of charges, all the time, required an ontological shift in her thinking about objects. This was not easy for her, as the next portion of transcript shows.

- Donna I just, I just still have a problem with um, that thinking that metals have both positive and negatives.
- Anne Would you put it was negative, like we just said for in the unrubbed nail?....
- Marge Would you have any other expectations down here?
- Donna I don't know. I'm feeling like
- Marge Like you don't know quite what's going to happen?
- Donna Yeah.
- Anne That's okay.
- Donna Well I'm just thinking that when you stick
- Marge What would you want to put in those boxes, cause I don't want to be running this thing.

- Donna No, no, no you're not, no you're not. See I don't feel . . . the only thing I 'm just thinking of is when you put a magnet on to a refrigerator, it sticks cause that refrigerator has to be negative. It doesn't have positive and negative in it. I don't know. I don't know. That's what I'm just thinking in my head.
- Marge Mmm hmm. So you're thinking that they're all negative
- Donna I don't think that the refrigerator is full of positive and negative
- Marge And when you magnetize something it makes it a positive.
- Donna Yeah
- Marge Okay That could be true too. But in the same case you'd have an attraction.
- Donna I don't know
- Marge Whichever is happening.
- Donna Yeah

Besides Donna's conceptual/ontological difficulty, two other issues jump out of this discussion. One is Marge's attempt to ameliorate the problem of having two different ideas. Marge said "I don't want to be running this thing" which illustrates the common ground norm in the group. Group members were obliged to make responses on the computer documents that all members could accept. Donna was the group typist this day, and during this conversation she sat with her arms crossed. It was apparent that she wasn't ready to begin typing a response. Perhaps the group had not achieved a common ground yet. So Marge, who had brought up her different model, said "Okay. That could be true too" referring to Donna's model.

The other issue apparent in the discussion above is Marge's attempt to compromise with Donna by searching for ideas that they had in common. Marge that regardless of what they thought was going on in the nail, it would still attract all of the pieces of metal wire (so the group thought.) This also can be seen as constituting the common ground norm.

Donna had a problem because the 'one charge on each' idea couldn't explain why two unrubbed objects didn't repel each other. At the same time, she did not seem ready to accept Marge's separation model. Anne had already accepted Marge's model, so Donna, as the group typist, may have felt she was in the way of the group moving on in their work. And, Marge had attempted to compromise. Donna reached over to the keyboard and began typing Marge's idea.

- Donna But, um but I think that's really good about moving those- the positive ions down to the end .. of the nail.
- Marge Um ... Whatever, but we're all saying about the same thing
- Donna I think, yeah
- Anne Yeah, yeah
- Marge We're still saying that we're making the attraction happen
- Donna Yup
- Anne Mmhmm

Marge because of concentrating positives or changing charges to positive so that there's an attractive between positive and negative charges.

The group members seemed to be trying to convince each other that they were thinking the same thing, but they hadn't been. Donna typed the following response, supported by Marge and Anne via joint typing.

"We are making the attraction happen, because by moving the magnet in one direction, we are moving all the positive ions to the end of the nail - and concentrating them there. (There is a high concentration on the end of the nail of positive ions that make the attraction with other metals.) It makes the nail a magnet that attracts the metal! Positive and negative attract."

From the initial reading of the question to finishing typing this statement, the group spent nine and a half minutes in discussion. At the end of it, Donna had typed the brief description above, and she had acknowledged a model that represented a significant conceptual change for her and Anne.

This analysis of the video records suggests that norms were crucial aspects of the group discussion. The obligation to construct group responses that all members could accept seemed to be important, and it may have driven Marge's and Donna's attempts to compromise. The obligation to have a causal reason for predictions seemed to represent a proto-norm that later could be recognized as the obligation to have models that could be supported by acceptable evidence. The group's work at the computer also effected their dialog. Donna was able to cause the conversation to continue by moving her hands away from the keyboard. The group's typed statement was a result of collaborative suggestions made partly in response to the current, visible, incomplete statement in progress. There were other features of the group's interaction which have been hinted at, but it is clear that the group interactions which are described by the common ground norm and the joint typing category were part of an important change process.

But, did Donna's thinking undergo a conceptual change during those nine and a half minutes? This is not so clear. She seemed to have great difficulty with the separation model, and it is more likely that she simply gave in and typed Marge's idea. During the next Activity on the same day, Donna probably became much more willing to accept the separation of charges model when Marge used it to make specific predictions that were borne out in the group's experiments. Marge predicted that the two points of similarly magnetized nails would repel, and they did. After this, all three group members agreed on the separation model. In an interview on Day 6, Donna said that she still was not sure what was inside a magnet, but back when she said the magnet was only positive, she had been even more confused.

The group kept their separation model until after Day 7. How they changed is the topic of the next section.

Change from "Separation of Charges" to "Alignment"

The diagram below is intended to show that Marge and Donna changed to alignment models between Day 7 and Day 8. Anne changed sometime after Day 8, although she typed the group's explanations using alignment models on Day 8.

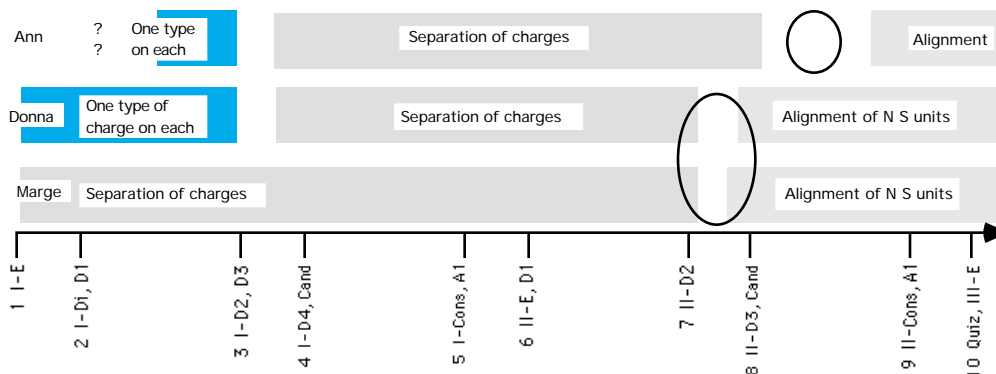


Figure 5-12: Second model change within the small group

On Day 6, the groups did an experiment intended to challenge the separation model. This was Activity II-D1, which is described in Chapter 3 and in Appendix 1. Each group magnetized a nail that had been notched for breaking, and then broke it. They tested for attraction or repulsion at each end of the two pieces. The intended outcome was that each piece would act two-ended like a normal magnetized nail. When Donna, Marge, and Anne did this experiment they found that both ends of one nail piece attracted to a second magnetized nail point, and they modified their separation model to account for what they saw. Their modification accounted completely for their observations. Appendix 3 provides the complete transcript from that Activity, with activity types and evidence for norms indicated. At the end of that Activity, the group represented a magnetized nail this way:

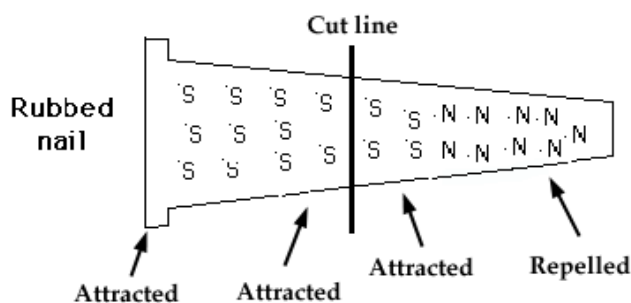


Figure 5-13: The group's model and experimental observations

Had the group gotten results that the teacher expected, the broken end of the head piece would have repelled. The pattern should have been "attract-repel-attract-repel" in the diagram above. Other groups did see this result.

Marge, Donna, and Anne were aware that other groups had begun using alignment models. At the very end of Day 6, the group talked about the alignment diagrams they saw on other groups' computers. Then, on Day 7, the instructor repeated the nail breaking experiment because some groups including Marge, Donna, and Anne had seen other results

due to an unforeseen experimental difficulty - the pliers used to hold the nail had been magnetized.

At the beginning of Day 7 the instructor displayed the results of all ten groups, and then he demonstrated attraction and repulsion at the two ends of each broken nail piece. These two acts gave official sanction to those results as the accepted class observation. Students' responses to these results provide more support for the evidence norm. Thus, Marge, Donna and Anne had a model that they couldn't support with acceptable evidence. But according to the models norm, they had an obligation to have a model that could be supported with acceptable evidence.

The group anticipated that they might get an idea for a better model from the day's Activity, but they didn't. Activity II-D2 (described in Chapter 3) dealt with issues of the size of nails, partial magnetization, and superposition of magnets. At the end of the day, Marge and Donna were aware that they needed a new model, but they didn't have one yet. They spent some time discussing possible modifications to their alignment model. Marge proposed that perhaps the charges in the middle of the nail remained mixed until the nail was broken, and then they moved. A diagram is suggested below.

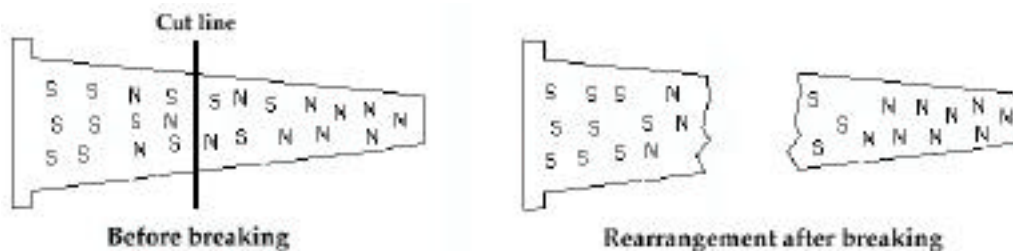


Figure 5-14: Marge's suggestion on Day 7

- Marge ...that each broken piece would act like a magnet. So maybe that's what's happening.
- Donna It's possible.
- Marge I can't think of any other thing. That could make it act like that. And that action would have to happen after the breaking took place. Because after the breaking takes place this end no longer has any attractive forces over here because it's displaced from it.
- Donna I don't see -this is so far fetched.
- Marge And the same thing here over there.
- Donna This is super far fetched, but I wonder, is it possible, that new forces are created? Like those little negatives, do they re- do they, make more of them?
- Marge [Laughs] I don't know.
- Donna I know, that's what I was thinking but,
- Marge I can't think what else is going on. I really can't think of it. But none of it, I didn't see anything explained to day that would have told us what happened in the middle of that nail. - - - What goes on in the middle of a magnet?

For some reason this group was not as willing to simply adopt the alignment model as other groups had. Donna's reason (which was mentioned above) for not doing so was that she wanted to have her own model, rather than use someone else's. It is clear that they tried to make the separation model work, but they weren't able to change it in a way that they could be satisfied with it.

At the end of the period on Day 7, the instructor gave the class a homework assignment. Students were to go home and draw their best picture of what was going on in an unmagnetized nail and a magnetized nail, and write down their evidence that supported their pictures. On Day 8, both Donna and Marge brought in their homework with alignment diagrams. Anne drew a separation diagram. Thus two of the three students had changed their models outside of class, away from the video camera.

Still, it is quite likely that Donna and Marge were motivated by senses of obligation that we would call the models norm, that is, they had to have models that they could support with admissible evidence. There certainly were other reasons why they changed to the alignment models instead of using a model that required rearrangement upon breaking the nail. When asked on Day 8, both Donna and Marge explained that they had changed their models because they couldn't get the separation model to work.

Marge said that she had gone to the library to do the homework for the class. She said, "I'm thinking about this all the way. Remember I was so upset about the broken nail. I couldn't figure out why it came out the way. . . And all the ways that I was thinking of the concentrations of pluses and minuses or north and south would not agree with that breaking principle. . . in my mind." Sitting in the library, Marge looked through the pictures she had drawn of other students' models during the Cycle II Elicitation, and she found the alignment pictures. She reasoned that those could explain the broken nail results, and so she switched to an alignment model.

I interviewed Donna right after class on Day 8 when she turned in her homework. She said that she had been thinking about her problem, and she changed to the alignment model: ". . . my model changed. It changed because, well I sort of resorted back to somebody else's model and I was telling [the instructor] I was concerned about that. I felt disappointed and I felt, well, I was frustrated because I couldn't come to my model on my own, I had to use somebody else's idea." Donna was very aware of the problem presented by the broken nail results. She said, "if you break a nail, and it acts like a magnet, there still has to be north and south forces or positive and negative in each piece." Apparently she found that the alignment model would allow this. Donna repeatedly said, however, that she felt kind of bad that she couldn't get her model to work. It may be that she learned to think that way in other classes, which could have had classroom norms enforcing individual work. She explained this again:

- Donna But it's like I was trying to prove my model and I wasn't very open minded about other peoples' models.
- Intvwr. yeah? That's an observation about your . . .about yourself.
- Donna And then I decided to be a little more - Yeah, so I decided to be a little more open minded towards - other peoples' models. And then I felt sort of bad for doing that.

The instructor told Donna that in this class, sharing ideas was a good thing.

It seems evident that some obligation to have a model that could fit with classroom evidence was driving both Donna and Marge. This was probably the model norm, and the evidence norm. In addition, the effects of previous classroom norms may have encouraged Donna not to use alignment models earlier. Clearly, the group members would have faced the problem with separation models sooner if both of their nail pieces had been two ended. Thus, some norms played a part in Donna's and Marge's changes, but so did the accidental magnetization of pliers.

Because Donna and Marge changed their models outside of class, I can't analyze the events right before either one changed. Instead, I will describe what happened to Anne in the group's discussion on Day 8.

On Day 8, the groups worked through Activity II-D3, which was intended to provide an analogy for the alignment model of a test tube filled with iron filings. Marge and Donna had both adopted alignment models, and Anne had not. At the beginning of their discussion, both Marge and Donna explained how they had (separately) come to use alignment models for different reasons. Then the group talked about how they would represent their model on the document as was requested. They spent some time talking about whether they should draw + - symbols or N S symbols. Then Donna asked Anne what her thinking was, as she had not talked about models yet. Anne had stuck with the separation model, and she came up with a clever reason why the broken nail pieces were two ended. This is best described in her own words.

- Donna What's your conclu - what did you draw to turn in? Did you change your model?
- Anne What I had, I didn't use it, but what I'd do, is like for an unrubbed, I would have them all mixed around, and I would use like positive and negatives, and for the rubbed nail I would have negatives at one end and positives at the other.
- Donna yeah, So you ha-
- Anne basically meeting in the middle.
- Donna So you. . Oh.
- Donna See but what happened, see, what we just did in class,
- Anne Mhmm
- Donna let's say you put all your souths here or your positives here and your negatives here?
- Anne Uhuh
- Donna remember he broke it up in different pieces?
- Anne uhuh, and the nail [?]
- Donna See he just broke off that little tiny bit of bit,
- Anne Uhuh
- Donna It still acted as a positive and
- Anne [?? whole nail??]
- Donna yeah, it still acted as a whole nail.

- Anne I was telling [Marge] how I see that is that it's sorta like when, um, okay well anyway, how I see that is, when it breaks up, the nail is like, "Oh, I'm my own nail now, I have to be both negatives and char - positives."
- I think it just does it on it's own sorta like neutrons, posi - uh, we were studying about - yesterday we were talking about electrons protons and neutrons a lot of times turn themselves into protons and an electron. in electromagnetism and I was thinking about that how, they turn themselves into it.
- So I was just thinking that the rubbed nail does that to itself.
- Donna you mean automatically
- Anne uhuh
- Donna creates a negative and positive.
- Anne I'm relying on faith.
- Marge [laughs!]
- Donna I don't think so.

Anne said a number of interesting things. She almost said "negatives and charges", which is an idea from the group's discussion at the very beginning of the unit. Anne might not have begun to think of positive and negative charges as equal but opposite. Instead, she may have almost intended to mean that negatives were not charged. Also, Anne was taking another science course, in which the phenomenon of neutron decay had apparently been described. She supposed that maybe a similar phenomenon was taking place in the broken magnet pieces, which could explain how the opposite charges could "appear" at the broken ends of the nail pieces. Donna had actually considered this possibility at the end of Day 7, but she abandoned that idea for some reason. Apparently it didn't seem reasonable to her.

The response that Marge and Donna gave Anne's explanation suggests which kind of model drawing this group decided to make. Anne's idea was not accepted. The question that remains is how or whether the group constituted the common ground norm. Did they come to agreement before drawing a picture? The following piece of their discussion shows that they did look for a compromise. Fortunately (or unfortunately) for Anne, she was the typist for the day.

- Anne What do you guys want to do?
- Marge Well, this, we just have to do this quickly, because we've gotta do the experiments, and then we have to start writing. We have to make up a model.
- Donna I think there's units of positive and negative unit of - unit of neg
- Anne You mean like the boxes? How they were showing that?
- Donna Well, there's a unit, it's got a positive and negative or a north south. There's another unit that's got a positive negative or north south.
- Anne Uhuh
- Donna There's another unit. And then what, when they're rubbed, it gives directionality.

- Anne That how you say it too, Marge?
- Marge Uhuh.
- Donna [To Anne] Okay, but if you don't , we,
- Anne Well, no but that's sort of what I was talking about.
- Donna Two of us against Anne. [laughs]
- Anne No, no, no well what I was talking about was the unrubbed nail was I see them mixed up
- Anne I guess I can see the box it doesn't make any difference to me. It don't think that's more complica
- Anne I can see that, that to me is basically the same as what I was saying, north and south mixed up or positive negative mixed up.
- Marge Mhmm
- Anne How you guys are saying you see boxes of them, and then that give it directionality. That's basically what I see.

Donna's statement to Anne "Okay, but if you don't , we, " may have represented a token attempt to ameliorate Anne's difficulty in thinking differently from Donna and Marge. After that, Anne's reply constituted the common ground norm similarly to how Donna talked just before she changed - she found a way to say that their drawing was consistent with what she was thinking. Anne claimed that her model was more or less the same as Donna and Marge's models. Actually, she was referring to the model of the unrubbed nail only, which would look the same in both models if she ignored the boxes around the NS pairs, as she did. Without boxes holding the NS pairs together, the unrubbed nail in an alignment model looked like an unrubbed nail in a separation model, as there appeared to be a mixture of N and S in the nail.

Possibly because the group members had all seen alignment diagrams on other groups' computers, there was little discussion about how to draw the diagrams. Thus, processes of joint typing and/or checking may not have been important to Anne's drawing of the model, and possibly to her change in thinking.

The group talked about the + - / N S issue while Anne drew NS pairs in an unrubbed nail. Then the time came to draw the group's model for a rubbed nail. Anne had not agreed that the alignment model was like her understanding of a separation model, but there seemed to be little she could say.

- Anne Okay, then, so the rubbed nail, you just think, so basically nothing, we don't, still don't know what's going on in the nail, just put the south
- Donna No, I would put it all throughout it, because no matter where you break it,
- Anne That's what I was thinking.
- Donna Yeah, all throughout.
- Marge Yeah, just make em all,
- Donna Yeah, so if you did it like that you go, north south north south all the way across.
- Marge all the way across.
- Anne Okay

After this, there was no more discussion about which kind of diagram the group should draw. By saying "we still don't know what's going on in the nail" Anne may have been attempting to suggest a nail diagram that didn't explicitly show aligned NS units, but Donna said no. Anne was technically correct to say that the group still didn't know what was going on in the nail. However, both Donna and Marge had an idea that they thought worked. Then Anne said "that's what I was thinking." The diagram Anne drew is shown below.

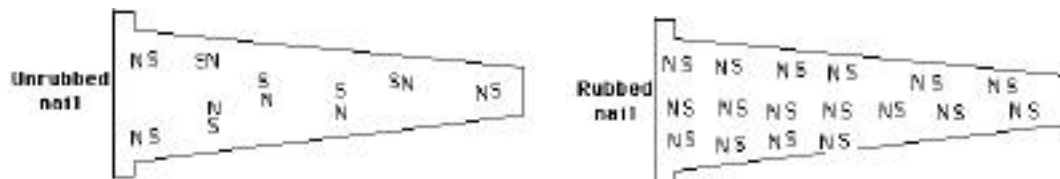


Figure 5-15: Nail diagrams that Anne drew

Based on this example, seeing the common ground norm as a description of a static pattern of obligations may not help us understand everything that was going on in the group this time. Anne did not seem to accept the alignment model very well, but she drew an alignment diagram anyway. The concept of norms requires that they be changeable since they are interactively constituted, so maybe the common ground norm was changing. Alternatively, there certainly were other influences on the group's interaction besides that particular norm. Donna and Marge were clearly the intellectual leaders in the group, so maybe their confidence "forced" Anne to take a follower role. Or, the group realized that their time was limited and they had to get working on the rest of the Activity document, so they couldn't continue to talk about models. Whatever the reason, the group seemed to interact differently during this time.

While working on the next Development document, the group members saw clumps of iron filings move around and "align" inside a test tube when they moved a magnet across the top of it. Marge and Donna continued to talk about the alignment model, and they used it to make predictions of the test tube's behavior in different situations. Their apparently successful understanding, as well as some successful predictions, seemed to provide evidence of the usefulness of the alignment model. Anne was particularly impressed when the group successfully predicted that a nail would lose some of its magnetization when hammered, just like the test tube became unmagnetized when it was shaken.

Anne apparently got used to the alignment model. At the end of the Activity, the group was presented with an opportunity to redraw their group model again. Anne said to the others: "Now that we're looking at this, do we want to modify our model? [??] if we would. I, I agree with you guys like I basically had the same idea with them all mixed around. I just [didn't have?] a unit but the unit doesn't really like complicate my thought. It doesn't make any difference uh- ah- [??] if anything it will help."

When I interviewed her a week later, Anne said that she had adopted the alignment model (which was not surprising, as by then it was the class consensus model.) Anne said that it took her a few days to get used to the idea, but once she did, she understood it and understood why it was better than the separation model.

In making this change in the group, it appears that Anne had to accept the alignment model in order to support the common ground norm within the group. What happened this time did not involve as much give and take among members as the group showed previously. However, Donna and Marge were convinced that their alignment models were the ones they should be using, and they were satisfying another norm, that of having models they could support with acceptable class evidence.

The successful development (or in this case, adoption) of an alignment model by this group does not mean that they understood magnetism completely. There unfortunately were still gaps in their knowledge. One gap was the group's resolute unwillingness to claim that magnets had NS or "units" instead of + - charge "units". They did not do a conclusive experiment that would have determined whether the charges in magnets were the same as the charges in electrostatics. So the group as a whole said that they didn't know for sure. Here is an excerpt from their discussion during the test tube Activity:

- Anne . . . for me I don't know if it's north or south or positive negative.
 Donna do you have a feeling if it's positive negative or ?
 Marge I would rather put north south because I don't know if it's positive or negative. To me, positive and negative means just like "a" and "z" or north and south or opposite ends of something. So if you're more comfortable with positive and negative
 Donna I think that they're both representing the same things When I think of north and south I think positive negative
 Marge yeah

However, the group members were able to apply the magnetic alignment ideas on a test and in interviews, and list reasons why the alignment model is more useful than the separation model.