The Role of Scientific and Social Academic Norms in Student Negotiations while Building Astronomy Models

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Abstract: This paper contrasts two groups of students as they build models to explain the phases of the moon. The group with a more successful model and more coherent final explanation judged their own work against scientific norms explicitly throughout their building process, while the less successful group remained focused on social and academic norms as they evaluated their work. When students explicitly invoked particular norms, subsequent arguments tended to coalesce around the explicitly identified norm. Particular strategies for dispute resolution aligned students with either scientific or social academic norms. We suggest the need to make norms and the negotiations around norms visible for students and to encourage science students to use scientific norms when evaluating their work.

Introduction

In this paper we examine peer interaction in two groups of children attempting to build models of the moon-sun-earth system that can explain the phases of the moon. One group's model was quite successful; in a series of presentations multiple group members were able use the model to accurately explain a new moon, full moon, and the waxing and waning quarter moons. In addition to the model's suitability for conveying key ideas about the earth-moon-sun system, the social process of building the model was an effective platform for collaborative learning: every group member was able to produce an accurate written explanation of the phases of the moon by the time they completed their models. The other group, in contrast, built a static model that only worked to explain a quarter moon. Their verbal explanation of their model was also plagued by confusion between the conditions for a new moon and the conditions for a lunar eclipse. At the end of the project, only half the group members were able to explain the phases of the moon on paper.

In this paper we argue that the trouble experienced by the less successful group comes from a tension between the social/academic norms of their school at large and the specifically scientific norms that are also invoked in the double-layered social space of the science classroom. We will show students in the less successful team "talked past each other" by speaking from different sets of norms whereas students in the more successful team managed to engage more productively in debates that drew on social/academic norms at some times and in science-based norms at other times. We will point out particular moves made by students in the successful group to increase intersubjectivity, make the grounds of disputes explicit, and enable them to reach flexible resolutions more quickly. Our primary aim here is to use examples of small group discourse to illustrate how these two sets of norms operated and sometimes conflicted, the active role children took in negotiating which norms were relevant to their work, and the consequences of particular orientations towards these sets of norms for children's learning.

Background

Academic researchers typically conceive of children negotiating different sets of social norms and values as they move between different social spaces through the course of a typical day, such as the transition from home to school and back (e.g. Heath, 1983). But even within one context, multiple sets of norms and values may be at play. For instance, within a science classroom students may experience tension as they try to make moves that are valuable within peer culture on the one hand or within scientific culture on the other (Brown, 2004, Enyedy, Danish, & Fields, 2011). We adapt a distinction made by Cobb, Stephan, McClain, and Gravemeijer (2001) to identify social academic norms and science/engineering specific norms. Social academic norms delineate expectations for students and the teacher irrespective of the subject at hand, whereas science-specific norms derive from scientific discourse and are specific to work in science class.

Additionally, we recognize that students' modeling activities are heavily mediated by and negotiated with their peers. Peers offer recommendations, critiques, and demand that others be accountable to norms that directly or indirectly renegotiate the various norms of behavior that have been established within the classroom. Through the experience of building a representation, students make use of a variety of resources including norms about representation and particular skills and practices related to modeling. Danish and Enyedy (2007) showed that students appear to respond to local contingencies to decide which norms are relevant to the decisions they are faced with as they create representations. We build on this notion in the current paper by looking closely at the ways in which interactional moves are aligned with or undercut the norms and engineering practices of two groups of students. Our goal is to examine how each group's alignment with particular norms affects their cooperation, their learning, and the model they create.

Method

Setting and Curricular Unit

Data for this study come from a classroom of fifth grade students in a progressive laboratory school in an urban center of Southern California with an ethnically and socio-economically diverse student body that roughly mirrored the population of the State of California. The school uses the Reggio Emilia approach to education, stressing the importance of making and evaluating representations in a broad range of educational activities. On a day-to-day basis at REA, the central way students were evaluated by teachers was through their ability to contribute in valued ways to whole-class discussion. Instead of grades, report cards at REA include detailed assessments of how students are performing in specific areas of academic and personal development.

Data come from a project in which students were challenged to build a model that could explain the change in appearance of the moon from our vantage point on Earth. For two weeks, students marked the position and appearance of the moon in the sky at night as homework. In groups of 4, students compared their observations to discover that the moon looks very different in the sky from night to night. Each group discussed their own theories as to why that might be and devised a brief skit to demonstrate their own theory of why the moon looks different. Initial explanations demonstrated a variety of conceptions about the apparent changes in the moon. For instance, one group expressed the idea that the moon is just covered up with clouds on some nights while another suggested that the moon folds in upon itself to become a thin sliver one night and re-expands to a large ball another night. Some groups included a sun in their model, some included an earth, and some included an observer. All groups had one student playing the moon, but other "characters" also appeared, such as clouds, stars, an observer on the earth, and a narrator. After expressing initial ideas in these models, each group was asked to write a list of questions they would need to answer in order to best explain why the moon looks different on different days or nights. Finally, each group was given the moon model challenge in which they were presented with one of their own observation drawings that they were challenged to explain with their model. They were given and a planning sheet to help them organize their ideas for model building, a variety of craft supplies, and a list of web resources that might be helpful for research.

Participants

For the present analysis we selected 2 student groups: Team Orbiting Moon, who constructed an especially successful model and in which all group members displayed an excellent understanding of the phases of the moon by the end of the project; and team Fixed Moon, whose model was less successful and in which half of the group was still unable to explain the phases of the moon accurately after the unit. The teacher assembled groups to be gender balanced (2 boys, 2 girls) and heterogeneous with regard to students' prior science performance. Both groups of students began their task with comparable background knowledge: each group had two members who responded to the pre-interview question on why the moon looks different with some version of "I don't know" while 2 other group members had partial understandings of the mechanisms behind the phases of the moon. Both groups spent a similar proportion of their time "on task" (working on some aspect of planning or building their model). Their interactions with the teacher were similar in nature: she visited each group about half a dozen times during the build and her visits typically refocused them from off-task conversations.

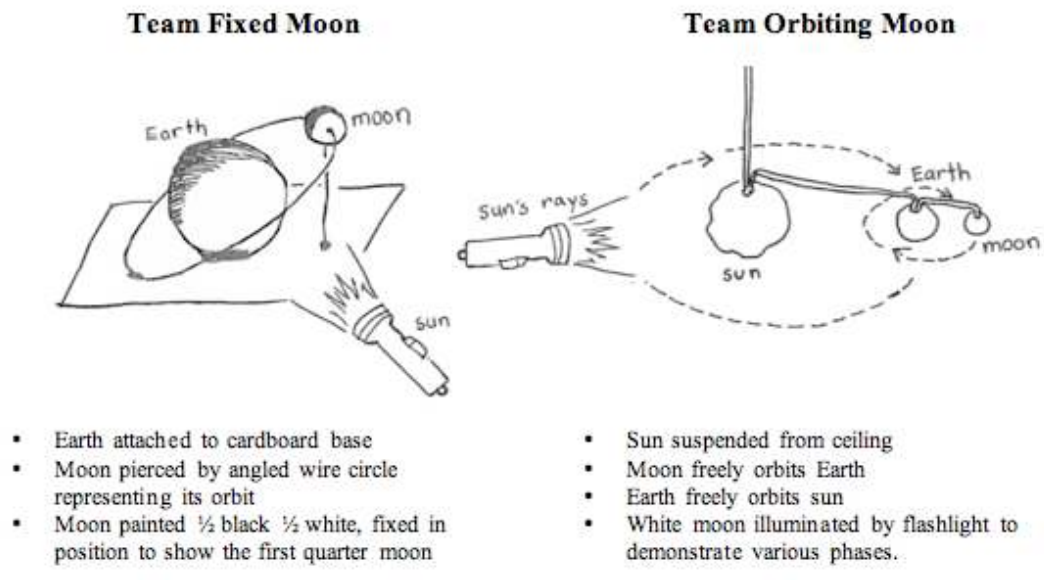

Figure 1. A comparison of Team Fixed Moon and Team Orbiting Moon's models

Team Fixed Moon has made a few representational commitments that limit their ability to successfully depict all the phases of the moon (see Figure 1). They attached their moon to the cardboard base and to the Earth so that if they want to represent a different phase of the moon, they have to either move the sun (giving the unfortunate illusion that the sun rotates around the earth) or break the model and rotate the moon, in which case the side they painted dark becomes incorrectly positioned relative to the sun. Additionally, while, presenting the model, more than one group member makes a critical mistake which belies basic confusion over how the phases of the moon work. Two of the students spoke of the shadow of the earth blocking the moon from the sun's light (a lunar eclipse) as the cause of new moon. The alignment of the planetary bodies they used to illustrate a new moon would actually produce a full moon. This confusion is common because the motions that produce eclipses are complex and the variable angles of the moon's orbit relative to the earth's orbit is rarely well-depicted.

Team Orbiting Moon's model, in contrast, was better able to represent multiple phases of the moon because the moon could be rotated around the earth freely and because the moon was not painted, allowing for a light and shadow to change as the moon orbited the earth. More members of Team Orbiting Moon skillfully explained this model during their final presentation without any major mistakes. Finally, all of Team Orbiting Moon's participants could successfully explain the cause of a new moon and a quarter moon in their individual final interviews after the unit was complete.

Data and Analysis

There were three sources of data for this project. Classroom video of students presenting their final models was coded to indicate the sophistication and scientific accuracy of the model and the explanation students gave of their model. Individually administered written and oral pre-post questions prompted students to explain the phases of the moon and were coded for accuracy so that we could find out which group members could successfully explain the phases of the moon on their own. Finally, classroom videos from the 3 key lessons of this unit (an exploring day, a planning day, and a building day) were recorded. We analyzed these recordings for student reinforcement of norms.

During the flow of work, norms are not always apparent to an observer. Participants make norms visible when they evoke them in evaluating themselves and their work. Therefore, we began by identifying all the times norms were invoked in each group across the classroom footage to identify any/all the times students made judgments or evaluations of their work. Norms about how students should contribute to class surfaced in students' corrections, compliments, and complaints to each other as well as in more formal evaluations such as their final presentations. Students may explicitly flag the set of values by which they are judging contributions to the model or may make comments that implicitly suggest the student is speaking from a particular set of values as they make their judgment.

These evaluations often sparked discussions and arguments about the work as students disagreed either with each other's evaluations of the model or with proposals to improve it. We termed these conversations in which the students explicitly debated judgments of their own work (or the social process by which that work was being accomplished) "evaluative exchanges." Evaluative exchanges differed from other on-topic working conversations because they involved critique: someone's contribution was being judged against some set of norms. We identified the 31 evaluative exchanges that took place within the three selected lessons. Within each exchange, we identified all of the norms being invoked by students as they made their judgments. The specific norms identified were then grouped into two categories: social academic norms or Science-specific norms. This parallels a distinction commonly made in mathematics education research between social norms and sociomathematial norms (Cobb, Stephan, McClain, and Gravemeijer, 2001). Social academic norms help participants coordinate school-based activities by delineating expectations for students and the teacher. These norms would not be expected to differ substantively if the teacher and students were working on an art project or history lesson rather than constructing scientific models. Science-specific social norms, on the other hand, outline a set of shared expectations for scientific work in the classroom. In a prior analysis of a classroom at this school, Cook (2011) found that some of students' science-specific classroom norms echoed the commitments of formal scientific discourse in the adult world while others stemmed from popular images of science and scientists. Therefore, to determine if a norm was science-specific, we considered first whether it would be relevant in a non-science lesson and secondly whether it corresponded to the core commitments of scientific discourse and/or popular notions of what being scientific means. Occasionally group members made it explicit which set of norms guided their evaluation (see science-specific norm 1 below for an example). In these cases, we were able to bolster our analytical judgments with participants' expressed perspectives.

In some evaluative exchanges, more than one set of norms were referenced during the course of the discussion as the students evaluated their work in terms of both social and scientific expectations. In most of those cases, exchanges drew more much more heavily on one set of norms than on others and were classified in terms of the set of norms underpinning the majority of evaluations within the exchange. One exchange (discussed in the subsequent section) was identified in which students drew equally on science and school norms. Two researchers reviewed all of the exchanges and agreed on their classification.

In this paper, we selected one evaluative exchange from each team for a closer qualitative analysis. To make this selection, we looked for the moment at which each group made the key representational decisions that led to the differences between their final models. For the selected conversations, we created vignettes transcribing and describing each argument. We then analyzed these vignettes them in terms of the way students alluded to the norms that influenced them, the rhetorical moves they employed, and the implicit rules for resolution the group seemed to be operating under as they worked together. After comparing the selected evaluative exchanges on these terms, we looked back across all the exchanges to see if similar patterns were evident.

Results

Types of Norms Referenced by Students

This list of key Science-specific and social academic norms is not exhaustive but represents the most frequently referenced norms in the group work we reviewed.

Table 1. Most frequently referenced norms during the moon model challenge.

Science-specific Norms
1) Judge ideas by how well they correspond with your scientific prior knowledge. Example of norm in use: Atticus made a perfectly reasonable suggestion, from an engineering perspective, when he suggested that the group could spin the moon, let it twist, and then let it automatically untwist itself when it naturally began to spin in the opposite direction. His idea was rejected by two group members, Iman who said "I am pretty sure the moon doesn't go like this then go like this [pantomiming clockwise and then counterclockwise rotation] and Marie, who explicitly framed her objection to this idea as a science-based argument by sarcastically saying "Oooooh so scientific"
2) Prioritize scientific accuracy over other engineering concerns. Example of norm in use: Team Orbiting Moon works hard to engineer a structure that will let them accurately represent their understanding of the motion of the planetary bodies and reject construction options that would have been physically robust but would not have moved in the ways they believed the planets to move.
3) Omit details that don't affect the phenomenon you are modeling. Example of norm in use: Team Fixed Moon cut clouds out of their design fairly quickly. Like the fists, clouds appeared in many students' initial drawings, but Team Fixed Moon decided midway through Design Day to omit them despite the fact that Sammy had the materials selected. Marie judged that "we don't need clouds" explaining that clouds weren't part of what they needed to show.
Social Academic Norms
1) Everyone should contribute ideas to the project and share responsibility for work. Example of norm in use: Students routinely called each other out for not contributing enough to the work and frequently paused to review their work and assign authors to all the ideas currently represented in the representation for the purpose of assessing the division of labor.
2) Each group member should understand / be able to explain the project. Example of norm in use: Students held the expectation that any of them might be called upon to explain any part of the project at any time and felt that part of building a good model was that each team member be able to use the model to explain the phenomena of interest.
3) Pick the easiest way to do your project. Example of norm in use: In both groups students offered evaluations based on the ease of a proposed idea: "[choosing to answer] that question will be too hard" or "It's gonna be way easier to act this out than to build it."
4) Judge ideas based on how good of a grade you think you might get for using them (or the chance of provoking other teacher reactions such as 'getting in trouble' for a particular choice) When reasoning from school-based norms, both groups balanced priorities between choosing an easy approach and trying to get a better grade, as when Team Orbiting Moon rejected the idea of acting out their entire model because they believed "we'll get a better grade [if we build a model] than if we act it though"

Socio-academic norms at this school draw on reform schooling discourses and have been carefully established and cultivated through the sustained effort of teachers, staff, and students. Years of being pushed to take shared intellectual responsibility for group projects has led to a stronger commitment to collective ownership of ideas and democratic processes for creating and editing in small groups here than one might expect to see in a more conventional setting (Ryu & Sandoval, 2012). In addition to norms based on the practices of progressive education, participants also invoked more generic academic norms derived from conventional schooling practices and are related to the procedural aspects of moving through work efficiently and in a way that will be well-rewarded.

Differing Strategies for Dispute Resolution

When multiple sets of norms are at play and students have prioritized them differently, disagreements are inevitable. In the evaluative exchanges we examined, students use a variety of strategies for dispute resolution.

Appeals to authority versus focus on convincing each other: During their debate over whether or not their model should have fists in it, Team Fixed Moon appealed to the following sources of authority: the text of the assignment itself, whether or not another group was using the fists, the teacher's judgment, the opinion of a neighbor and a lunar simulation website the students consulted. During the set of debates Team Orbiting Moon had about how to make their moon orbit their earth, no outside authority was consulted.

Convincing each other was more productive in terms of student learning for a few reasons: Primarily it was because the intersubjectivity built through the kind of argumentation Team Orbiting Moon engaged in helped all students to better understand the science behind their model. Secondarily: in these two cases convincing each other was actually also a faster way to resolve disputes which allowed Team Orbiting Moon to move on to the subsequent decision and get further with building and practicing their model.

Trial and error versus planning first, execution second: Team Orbiting Moon used "let's just try it" to resolve a few of the disputes considered in this analysis, Team Fixed Moon got hung up on unanimously agreeing on a plan before they started building. Being willing to operate with trial and error gave Team Orbiting Moon more time to work with their model in various forms and gave students concrete objects to reason with as they argued for or against particular representational or construction decisions.

Majority rules / trial and error versus unanimous decisions only: Both groups occasionally invoked majority rules and each group had at least one instance of a group member holding up the flow of work until a unanimous decision was reached. Unlike the other two dispute resolution strategies, it is not clear from the evaluative exchanges in these two groups that one style of dispute resolution is more or less productive than another: The dark side of majority rules decisions was that they could involve some self-suppression or oppression as students who weren't part of the majority "put up with" the majority view. On the other hand, holding out for a unanimous decision resulted in less work time for Team Fixed Moon.

Which Type of Norms Decided Arguments?

Team Orbiting Moon had a greater number of evaluative exchanges over the course of their project than Team Fixed Moon, with the balance shifting away from socio-academic disputes in the towards arguments about science and engineering as the lessons progressed. Across all three lessons, about 2/3 of the evaluative exchanges in Team Orbiting Moon were centered on scientific or engineering concerns, compared to about 1/3 of the evaluative exchanges in Team Fixed Moon. One exchange in Team Fixed Moon was double coded because it relied equally on social academic and Science-specific norms; it will be discussed in greater detail in the next section.)

Table 2: Types of evaluative exchanges for each group in each lesson

	Team Orbiting Moon (more successful model)		Team Fixed Moon (less successful model)	
Lesson:	Social/Academic	Science/Engineering	Social/Academic	Science/Engineering
Planning Day	2	0	0	0
Design Day	6	6	5	1
Building Day	1	7	2*	2*
total	**9**	**13**	**7**	**3**

* One evaluative exchange from Team Fixed Moon was double coded because it hinged equally on social academic and Science-specific norms.

Key Evaluative Exchanges from Each Group

Team Fixed Moon

The critical representational and engineering decisions which sent Team Fixed Moon into an unproductive cycle of planning and re-planning their model stemmed from a central argument over whether or not the group should build a model that accounted for the way the moon's distance from the horizon changes over time, which the group had measured by charting how many of their own fists they could fit between the moon and the horizon when they found the moon in the sky. The argument began when Zeke proposed building a model of the earth, moon, and sun as seen from outer space very similar to what he saw on one of the reference websites students accessed. Jean Carlos quickly agreed, but Megan (who was holding the planning sheet the group was supposed to use to draft a design of their model) didn't write down their design.

> "If you have the general idea of your model in mind, what is preventing you from putting anything on paper?" the TA asked. "We need to understand it," said Megan. [*Social Academic Norm 2*] "Who doesn't understand it?" asked the TA. "I don't understand it" Megan said. The TA asks someone who DID understand the model to explain it to Megan. Jean Carlos began first with an air of exaggerated patience "OK. MEGAN you know how it's a half moon right there? [pointing at the Lunar Simulator on his computer screen and continuing to speak without pausing for Megan's response] We're gonna build that. Exactly like that."
>
> Zeke points to the materials list where Megan has listed 8 small foam balls (she planned to stack them on the earth to represent the 8 fists in Gianna's observation.) He asks Megan "do we have to have the fists? Why do we need the fists?" [Zeke's object to including the fists seems aligned with *Science Norm 3* about omitting unnecessary detail]
>
> Megan answers that "that's what it says" [on the assignment sheet] and that they "have to represent what is in their drawing" so they do need them. (Megan's concern with the fidelity to the assignment references *Social Academic Norm 4* about evaluating ideas based on how they will be graded or judged by the teacher.) Zeke countered "[the other group] don't have the fists in their model." Megan asks Jordan from Group D if their drawing had fists in it. She said no, so Megan argued, "see? Not all of them have fists in them!"

Zeke was the first to call on the other group, using their model's lack of fists as evidence that the fists weren't needed. He used the appeal to authority (in this case, the authority of peers) to begin to resolve the dispute between his science-based objection to including the fists from Gianna's drawing and Megan's Social Academic argument that they should be included. Megan argued that Team Fixed Moon was given a different observation of the moon in the prompt for their model and therefore had a different task, reinforcing social academic norms. The group went on to repeat the argument several times, appealing to the TA, to the teacher, and to a researcher. Megan continued to voice objections to omitting the fists, emphasizing that they all had to understand and be able to explain the model and that she didn't understand how Zeke's model could show the fists (*Social Academic Norm 2*] without saying much about what she didn't understand. Eventually, with very little time left to build, the team settled on a plan that was an amalgam of Zeke's proposal and Megan's proposal. In their hasty compromise, they focused more on incorporating ideas from each student "fairly' (as social academic norm) than the science norm of correspondence to their understanding of reality.

Team Orbiting Moon

The evaluative exchange from Team Orbiting Moon presented here was one in which a key representational decision coalesced: the idea to have a freely orbiting moon attached to the earth by a rotating wire. The team had previously toyed with many potential strategies for creating a model that hung in midair and was able to demonstrate an orbiting moon. After debating whether or not to use string or wire, Marie began this evaluation by critiquing Atticus' latest suggestion that all the planetary bodies should be hung by string from a beam in the ceiling of their classroom. This key conversation came after brief exchange in which students debated using wire versus using string that we will summarize as well. Taken together, the exchanges show while a variety of types of norms were invoked in these exchanges, science norms began to take on more and more explicit priority over other norms.

> The Wire Versus String Evaluative Exchange began when Atticus asked "should we use string or wire" and all group members began to argue for one material or the other. Students made clear references to engineering norms as they argued by describing wire as sturdier or saying that with string it will be easier to spin the moon (*Science Norms 3 and 4*). Then the terms of the debate shifted when Sammy pointed out that the group had already requested wire on their planning sheet. This meant that, if the group was going to respect the order of planning and building their teacher had laid out in the assignment, they would have to settle for using wire because it was the only material they had asked for and the time to request materials was over. (Her respect for the procedural directions in the assignment and concerns about taking steps out of order reflect *Social Academic Norm 4*) Iman's response to this limitation was to propose cheating. He suggested that Sammy sneak the word " string" on to the materials list the group had written the day before using the same pencil she had used yesterday so that the group could go get some string and try both string and wire in their project. Sammy declined and reminded him that the group was being filmed. (Again, the concern for adhering to the teacher's directed procedure reflects *Social Academic Norm 4*) Then Sammy said "wait though, do you even think string will be better? Guys I think wire will

be better. Wire will be better to hold it up." (Sammy shifted to an argument that drew upon Science Norm 3 at this point, emphasizing which design would be most robust). At this point Atticus agreed, "Ok thin wire then."

A new evaluative exchange (the Orbit Exchange) began a few moments after this decision was settled. Atticus said that the group should hang the earth and moon next to one another on two wires and use their hands to make each one spin. "No" Marie said, "It can't all be hanging because it has to go around" she said while circling her left hand around her clinched right fist in the air in front of Atticus. (*Science-specific Norm 2*) Marie continued, "If the wire's supposed to be hanging [as she said this she traced two invisible wires down from the ceiling with the tips of each of her index fingers, then made fists at the bottom of the wires where the moon and earth would hang in Atticus' proposed solution] how do you make one go around the other [at this point she moved her right fist in a circle around her stationary left fist] without the wire getting twisted up?" (*Science-specific Norm 2)*

"I thought you meant it was just going to be spinning in it's own place" said Iman as he twisted his finger in front of him without moving his hand around the table (a gesture that evoked rotation as opposed to orbit" Marie banged the table and began to yell "Moons and earths don't//" when Iman interrupted "yeah I know, I'm kidding I'm kidding." (Marie's objection, though unfinished, seems to have been an appeal to *Science-specific Norm 1* as she compares the proposal with her understanding of what moons and earths do.) After a pause Atticus said, "we could let it get twisted up I guess. And then untwist it." Marie shrugged forward and said "soooooooo very scientific" as she shot a sarcastic half-grinning look at Atticus. "Yeah!" Atticus insisted, "It will go forward around, then it will go backward around." As he said this he spun his hands around each other clockwise and then counterclockwise to demonstrate a pair of objects tangling and untangling while hanging on two separate lines of string or wire. (*Science-specific Norm 2)* Marie said nothing, just let her half-grinning sarcastic look transform into a glare while Iman said, "I'm pretty sure the moon doesn't go doop doh doop" as he mimicked Atticus' hand gesture. (*Science-specific Norm 1*) "Wait, I have an idea!" said Marie. It was at this point that she sketched the initial draft of what eventually became team Orbiting Moon's final model. "We hang the sun from here, we hang the earth from the sun, and we hang the moon from the earth. So they can all go around each other," she explained, holding up the plan drawing. At first Atticus and Iman both objected that "this isn't gonna work" based on their understanding of her drawing. "These two would be going around the sun the whole entire time" complained Atticus, pointing at the moon and the earth in Marie's drawing. (*Science-specific Norm 1*) "no no no" Marie explained, "We can make it so that the moon is attached to the earth not the sun. so the moon can go around the earth." After leaning in over her drawing Atticus said "OH YEAH!" and team began to plan their model.

In the Wire Versus String Evaluative Exchange, Iman's suggestion of cheating suggests an explicit prioritizing of engineering and science norms over social academic norms because it demonstrates that he is willing to violate social academic norms in order to get the materials he believes will result in a sturdier build. While she declines to write the new addition to their materials list, Sammy doesn't object to Iman based on Social Academic norms, she offers her own engineering norm-based argument in favor of wire, which ultimately settles the exchange. Therefore the debate, while touching on multiple sets of norms, is settled in terms of science-specific norms. In the Orbit Evaluative Exchange, both Atticus and Marie objected to each others engineering plans by comparing the motions they would create to their understanding of the actual motion of the planetary bodies. What is more, Marie explicitly named the body of norms against which she was judging Atticus' suggestion when she sarcastically mocked his idea as "so scientific." Atticus later critiqued her proposal in a very similar fashion, arguing against her idea because he believed she was proposing to have the moon orbit the sun, which he called out as inaccurate.

Discussion

This analysis demonstrated that children in this science class had to negotiate multiple sets of norms in the dual-layered social space of their science classroom. The norms were not always harmonious, and there was not general agreement about whether social academic norms or science norms should take priority when they pointed students in differing directions. Instead, children used a variety of strategies for resolving conflicts that implicitly indexed different sets of norms. These resolution strategies were not neutral with respect to norms. In fact, depending on the strategy they employed, children were aligned towards either social academic norms or towards science norms. For instance, the strategy of temporarily agreeing to a solution and subjecting it to trial and error aligned Team Orbiting Moon with several science norms and led to deep conversations about the science behind the phases of the moon. Agreeing to trial-and-error allowed the group to achieve some degree of consensus around their design while maintaining flexibility. The dispute resolution strategy of trying to convince each other aligns children with the science norm that ideas should be judged based on their correspondence to reality, whereas making appeals to authority aligns students with the social academic value that ideas should be judged based on how well they will be received by the teacher or other academic stakeholders. The dispute resolution strategy of unanimous decision-making aligns students with the social academic norm that all group members should understand the group's project.

Which norms apply to which decisions was socially negotiated by children in the moment. These momentary negotiations built upon each other: one appeal to authority by Team Fixed Moon was countered by another appeal to a different authority and so on until the team had consulted nearly everyone in the room about their standoff over "showing the fists." This is an extension of what Anderson et al (1001) called snowballing. Anderson found that after the first appearance of a particular rhetorical stratagem, the probability that it would appear again rose. This analysis suggests that it is not only rhetorical moves that can snowball in group activities, but that orientations towards one set of norms or another and strategies for dispute resolution may snowball as well. Team Orbiting Moon provides an example of a productive snowball effect: their evaluative exchanges were more and more likely to hinge on scientific norms as time went by, particularly the norm of matching reality. This lead to a deeper engagement with the science behind the phenomena they were trying to represent. For team Fixed Moon, it was not a particular norm that snowballed, but the strategy of appealing to authority.

In most of their evaluative exchanges, children negotiated which norms should apply to particular decisions about their projects implicitly. However, Team Orbiting Moon benefited from particular conversational moves made that made science norms the explicit criteria of the groups' self-evaluation, such as when Marie teased Atticus that his idea to let the moon rotate the earth in one direction and then in another was unscientific. This comment and other explicit references to science served to reorient the group to science-related norms and set the stage for their productive engagement with the model-building challenge. After Marie's teasing, the group noticeably shifts towards arguing about the science of the moon-sun-earth system instead of their prior focus on the parameters of the assignment and the engineering benefits of using wire versus string.

To become more skilled at scientific representation, students need to practice evaluating their models with a critical eye, not just building them. This paper demonstrates that while building models, students used a variety of kinds of norms as reference for their judgments and that these norms were rarely explicitly invoked. When norms were explicitly invoked (such as when Marie teased Atticus for his 'unscientific' idea) students tended to coalesce around the explicitly named norm as a reference point for their subsequent judgments. A framework for explicitly describing the nature of their own evaluations and objections could help students to have better arguments and build better models by pushing them to articulate their arguments in terms of the norms upon which they are drawing. Future work should explore: 1) ways of making norms and the negotiations around norms visible for students and 2) ways of encouraging students to draw upon science-specific norms when they evaluate work in science class rather than relying only/primarily upon social academic norms.

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