Transforming Participation: A Case Study of an Introductory Physics Student in a Modeling Instruction Class

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Abstract: We present a case study on how participation of one student changed during her first semester of introductory physics class using Modeling Instruction. Using video recordings, we explore how her behavior is consistent with a change from thinking of group learning as a parallel activity to one that is collaborative.

The Physics Education Research group at Florida International University (FIU) has been implementing Modeling Instruction (Hestenes, 1987; Brewe, 2008), a reformed physics instruction curriculum and pedagogy, with introductory students. A primary goal of this reform has been to establish a sense of community among physics students at FIU, a large, urban, Hispanic-serving institution. Establishing a sense of community among students is of value because the academic and social integration of students into the university is strongly related to students' persistence in the university (Finn & Rock, 1997; Kreamer, 1997; Tinto, 1997) Achieving a sense of community among physics students at FIU is essential since nearly 48% of students are not retained in the first semester of physics (Brewe et al., 2010a). To evidence the formation of this community, we present a case study of one individual, Marta, and how her participation in the community of learners of her classroom changed while taking her first semester of introductory physics.

Modeling Instruction differs from typical physics instruction where students are passive and the instructor lectures. In Modeling Instruction, the laboratory and lecture components of the course are integrated into a studio format. Content is not delivered through lecture but, instead, students learn by building, validating, and extending models (Brewe, 2008). Class time is spent with students either working in small groups or discussing their ideas with the class, supplemented by information they put on portable whiteboards. Modeling Instruction changes the environment and activities in which students participate, as compared to traditional classrooms. These changes include seating arranged in groups, using experiments and whole-class discussions instead of lectures, and managing discussions to promote student-student discussions. While Modeling Instruction classes currently involve 30 student sections and, thus, impact about 15% of the physics students at our institution, students taking a Modeling Instruction course at FIU are more successful along several measures. Students completing Modeling courses show positive shifts on attitudinal surveys such as the Colorado Learning Attitudes about Science Survey (Adams et al., 2006; Brewe, Kramer, & O'Brien, 2009). They have improved scores on the Force Concept Inventory, a widely used test of conceptual understanding (Hestenes, Wells, & Swackhamer, 1992) and the odds of success are 6.7 times greater, compared to the traditional courses at FIU (Brewe et al., 2010a).

One of the goals of Modeling Instruction is to increase the successful participation of women and underrepresented minorities in physics. This goal has particular relevance for FIU, which teaches a majority of minority students. Moreover, most students commute, making access to activities that facilitate participation even more important. Students in Modeling Instruction are provided with many opportunities for participation in the classroom, where most of their

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activities require active participation. Previous research has shown that we are making progress toward this goal, as the Force Concept Inventory gains for majority and minority students in Modeling are not significantly different (Brewe, et al., 2010a). Additionally, a Social Network Analysis of students in a Modeling Course and a traditional course at FIU showed that all Modeling Instruction students worked with at least one other student (and most work with multiple students) while the majority of traditional students were isolates who worked with no other students from their class (Brewe, Kramer, & O'Brien, 2010b).

We have evidence that Modeling Instruction students are experiencing gains in both their conceptual knowledge and their attitudes about learning science, and these same students feel an increased sense of community (Brewe et al.. 2009, 2010a, 2010b). This has led to our investigation of whether and how a sense of community might contribute to student success. As students become part of a community of learners, the activities they participate in and their expectations about what it means to learn physics change. From a participationist theoretical perspective, this transformation of participation is learning (Rogoff, Matusov, & White, 1996; Sfard, 1998). However, what transformation of participation in a physics course looks like, at a fine-grained level, is not well understood. The case study described here is a part of our larger efforts to understand the community of learners that develops in a Modeling Instruction class and how individuals' participation is transformed as they become part of this community of learners. As such, we endeavor to address the following research question: *What evidence of changing participation can we identify from one student as she progresses through a Modeling Instruction physics course?*

Literature

The idea of community has been discussed in multiple ways in education research. Some researchers have restricted the definition of a learning community to a group of students who participate in courses spanning multiple disciplines, which last one or more semesters (Gabelnick, MacGregor, Matthews, & Smith, 1990; Zhao & Kuh, 2004). Others have defined learning communities more broadly as a group of people with varying levels of expertise and a group goal of expanding the community's knowledge as a whole, where no single person is responsible for or can know everything (Bielaczyc & Collins, 1999). We use Rogoff et al.'s (1996) term of a *community of learners* which is made up of active student learners and instructors that act as more skilled partners to provide guidance. In this community, both students and instructors have responsibilities for directing the learning. Students are expected to construct their own knowledge by participating in activities the instructor provides; within these activities, learners have choices regarding how to achieve their learning goals. In turn, instructors are expected to offer guidance but not to assume control of the learning process. The idea of a community of learners is embedded in the participationist understanding of learning, which is discussed in detail in a later section (Rogoff et al., 1996).

We use *sense of community* to refer to an individual student's perception of his or her social and academic integration in the community of physics learners. This use of the term *community* aligns with discussions of the role of social and academic integration in student persistence. Research on what influences students' completion of college, which is termed their persistence, gives us insight into what might affect students' completion of a course. In his synthesis of research results on persistence, Tinto (1993) identified several factors relating to community that influenced whether students completed college: their adjustment (or lack of it) to the new norms of a college environment, their perception of their fit into the dominant culture of the college, and how well they make social connections with other students. Moreover, both formal and informal faculty-student interactions have been shown to have an impact on integration on students in general (Tinto, 1993) and on the integration of Hispanic students in particular (Kraemer, 1997). Similar research on persistence in high school students shows the influence of their engagement behaviors, such as being prepared for and attending class, which are activities which can be supported by the classroom environment (Finn & Rock, 1997). In his comparison of commuter students attending traditional classes and those attending a class using cooperative learning to study multidisciplinary topics, Tinto (1997) suggested that learning communities improved persistence by helping students make friends, which led to more academic and social connections and more participation in the construction of knowledge.

Much of the research on persistence has focused on identifying factors that correlate to increased (or reduced) persistence. What is still missing is an understanding of how these factors appear in the daily interactions of students and faculty, and how a single individual's participation is transformed as she becomes part of a learning community.

Theoretical Framework

A community of learners requires analysis at multiple time scales and grain sizes. We depend on a participationist framework to clarify why a sense of community is important for successful physics learning. To answer the question of how day-to-day classroom activities contribute to building a community of learners, we will need to explain how people interpret and act in individual situations. To do that, we use framing, a theoretical framework developed in the fields of linguistics and sociology.

Participation Theory

Participation theory views learning as the transformation of participation. Students' way of participating changes as they learn the norms and practices of the community of learners, which includes developing a shared discourse with their fellow community members of students and instructors (Bielaczyc & Collins, 1999). As they engage in activities, students add to their knowledge and take on increased responsibilities in the community (Rogoff, et al., 1996). By this account, science students learn by engaging in activities such as discussions, doing experiments, and solving problems together. A student's participation in the community of physics learners is built up by all the interactions that she has with her fellow classmates, the instructor, and other physics students with whom she studies. Thus, the participation in the learning activities contributes both to the establishment and continuation of a community and to students' sense of how this community helps support their continuing participation.

Framing

Framing is the usually tacit process by which people answer the question, "What is it that's going on here?" (Goffman, 1974). A person's answer to this question is guided by her expectations of what kind of situation she is in, her past experiences of similar situations, and her perceptions of how others around her are framing the activity. For example, a student may frame working on a physics problem as an opportunity for sensemaking, which leads her to compare her computed answer to her own experiences. In contrast, framing the problem solving as requiring rote use of formulas might lead her to search though her textbook for a relevant equation. A frame becomes stable when it is repeatedly reinforced by the social and environmental context. Thus, the student in this example will be more likely to frame her physics homework as a chance for sensemaking if the other activities in her class, such as doing experiments and participating in discussions, as well as the attitudes of the other students, indicate that providing answers consistent with common sense and previous answers is valued and expected.

Methodology

Data Collection

The Modeling Instruction course is intended to be taken by students in their first or second year. The class has demographic characteristics comparable to that of the larger institution, which has a student population that is nearly 60% Hispanic, about half female and over 90% commuters (FIU Factbook, 2010). In the class, students work in groups of three, which are changed periodically throughout the semester. These groups work together to conduct experiments, analyze their results, and work on problems. About one-third of class time is spent in whole-class student-driven discussions, which are referred to as whiteboard meetings, because student groups present their results on portable whiteboards.

During the fall semester of 2010, we solicited student volunteers from the Modeling Instruction course being co-taught by Drs. Brewe and Kramer. We selected eight volunteers as study participants; they were chosen to maximize the diversity of academic and personal backgrounds represented. Each was interviewed at the beginning and end of the semester with a series of open-ended questions to elicit their perceptions of the community of physics learners and how integrated they were within it. In addition, two videographers videotaped the class of 30 students. Every day, each videographer chose a different group of three to follow throughout the day's activities. Videographers did not target the study participants, and as a result, each participant, along with his or her current group, was videotaped six or seven times during the semester.

Marta (a pseudonym) is a non-traditional student returning to college after several years working full-time. During her interview, she stated her intention to go to medical school, and has chosen to major in physics in part because she believes it will prepare her for this. We chose Marta as the subject of this case study because in her initial interview (during the third week of the semester), she said that she was comfortable asking questions in any class, including this one, and that she already did homework with her group members; we wanted to investigate how an outgoing individual, already comfortable with traditional ways of participating in classes, might have her participation transformed by taking a Modeling Instruction course.

Data Analysis

We use a case study methodology to study Marta's changing participation by focusing on two days of class, one in the third week of class and one in the eleventh week of class. Case studies allow in depth examination of a particular issue, in this instance, Marta's participation (Yin, 2009). This methodology is best suited to understanding this task because it does not seek to create a description of Modeling Instruction participation as an experience common to all the students who take it, but rather highlights the individual experiences of one student (Creswell, 1998). Two days were chosen to represent Marta's typical behavior at the start and middle of the semester. We considered the activities in which the students engaged on these days to be typical, as they are a blend of small group and whole class activities. Marta is working with a different group in each, and the particular activities of the day vary. The activities are discussed in greater detail below to illustrate how Marta's participation as a small-group member is transformed.
The analysis here focuses on Marta's participation in small group activities, as seen in a short episode from each day. This data is supplemented with information about her behavior in the rest of the day's class.

The beginning of the semester: Marta's group works in parallel. On the first day that we studied, three weeks into the semester, the students spent the first 50 minutes of class in a white-board meeting, discussing the homework problems they have been working on. They then worked for 45 minutes on a worksheet of quantitative problems in their small groups. Each group prepared one problem solution to present to the class, and they spent the last 20 minutes of class in a whiteboard meeting, presenting and discussing their solutions. During the first whiteboard meeting, Marta introduced and discussed in detail a homework problem with which she struggled, presented her group's problem solution, and asked questions of the other students. Even though she had only been in the class for three weeks, Marta asked questions, answered questions, and presented her group's whiteboard results more than the average student.

In the episode we have chosen to represent this day, the students had been given a worksheet with several problems to solve, but had only been assigned to do the first. The problem asked the students to draw motion maps and kinematic graphs (position vs. time, velocity vs. time, and acceleration vs. time) for the following situation "A subway train in Washington D.C. starts from rest and accelerates at 2.0 m/s^2 for 12 seconds." Student 1 (S1) and Student 2 (S2) were sitting on either side of Maria. They were each writing on their worksheets, with pauses between parts of their conversations. (The length of long pauses is noted in square brackets.) S2 asked Marta several questions, including how accurate the graphs should be and whether her assumption that the train is moving in a positive direction is correct. S1 also asked Marta questions about how to calculate position and whether the initial velocity (v-naught) is zero. At the end she asked a question about the initial velocity of the object in the second problem.

1 **S2:** Does it have to be accurate or are you
2 just drawing the general motion?
3 **Marta:** I'm drawing the general motion
4 and then I'm putting the numbers at
5 specific points, that are gonna be, like the
6 end points for example. I would put it
7 there. [22s]
8 **S2:** We just assume that it's in a positive
9 direction, right?
10 **S1:** Where's your position?
11 **Marta:** Correct. [Looks at S2]
12 **S2:** Zero.
13 **Marta:** We just need to reference that in
14 our motion map. It's consistent. [Turns to
15 S1]
16 **S1:** You use this one, how, v-t plus half
17 a-t-squared for di- position.
18 **Marta:** Yeah-
19 **S1:** Oh, no that's-
20 **Marta:** I did half times the base times
21 the height. Cause this is a true triangle.
22 So this here is-
23 **S1:** So our v-naught is zero.
24 **Marta:** [inaudible] Right.
25 **S1:** Right.
26 **Marta:** Right. Cause it starts at rest.
27 **S1:** Yeah. [66s]
28 **S2:** We only do the first one?
29 **Marta:** Yeah, he only wants us to do the
30 first one.
31 **S1:** But we don't know, [inaudible].
32 **Marta:** What's that?
33 **S1:** Here it is saying that it comes to rest
34 after skidding for thirty-five meters. We
35 don't know if they started at zero, right?
36 **Marta:** Right, but we only have to do the
37 first one.

In this episode, it is striking that Marta answered all of the questions (asked in lines 2, 9, 10, 23, 28, and 36) but asked none. Neither S1 nor S2 answered any questions, with the possible exception of S2's statement "Zero" (line 12), which seems only marginally connected to S1's question (in 10) and is also unacknowledged by S1. S1 and S2 addressed all their questions to Marta, and S1 even asked a question when Marta was still talking to S2 (line 10). All three students were working on separate worksheets and only looked at each other's papers to confirm answers. This behavior is noteworthy in a Modeling Instruction class, where students often work problems together collaboratively on a whiteboard. Last, S2 does not appear to hear S1's question or Marta's answer about which problem they have been assigned (line 28), because she asked Marta the same question less than 15 seconds later.

Two bigger ideas about Marta's participation are apparent in this episode. The first is that both Marta and her group mates consider her a source of knowledge, a reasonable assessment because during the entire group work session we watched since she almost always had a ready answer (although not always a correct answer). Marta did not appear to consider her group mates to be equal sources of knowledge: she asked them no questions during this episode, and when she did ask physics questions during the whole session, they were posed rhetorically, and S1 and S2 rarely answered them. (S2 does later provide a lengthy explanation on a calculus topic.) The other theme that emerged is that the three students perceive "working together" to mean "helping each other by answering questions." S1 and S2 seemed comfortable asking any questions that they had, and Marta never appeared impatient or unwilling to answer their questions. But their work happened in parallel, as evidenced by the long pauses where they were all writing on their own worksheets and the fact that they were all working on different parts of the problem at the same time. What is missing from their idea of "working together" is the idea that could they learn together: by brainstorming, clarifying each other's questions, or by working collaboratively on the problem.

The middle of the semester: Marta's group works collaboratively. On the second day we examined, Marta worked for twenty minutes with her small group to prepare a whiteboard explaining the experiment they conducted the previous week. In the hour-long whiteboard meeting that followed, each group presented the experiment they designed and the whole class discussed the results. The instructor then conducted a demonstration, and the last 35 minutes were a mix of students working in their small groups to make sense of the demonstration's results and a whole-class discussion led by the instructor.

In this episode, from the start of class, the students were supposed to be preparing their whiteboards to display the results of the experiment they did the previous week. Each group had to design their own experiment to test the effect of one characteristic on friction. Marta's group had already written up their whiteboard, so they were discussing their experiment, which was supposed to test whether the velocity of a moving cart affected the frictional force it experienced (it does not). They were unable to collect the data they wanted, so they modified their experiment; later during that experiment their instructor told them that they had tested how the mass of the object affected the frictional force it experienced.

1 **S4:** So I was thinking our, our, I guess
2 our project, our little thing proved that
3 um that the force of friction was
4 basically close to the force that we
5 applied by the weights.
6 **S3:** But we can't determine that because
7 we have no values.
8 **S4:** Well, we didn't, we didn't uh, we
9 didn't find out the forces of the weights,
10 right?
11 **S3:** No, we didn't find, because we were
12 so stuck, we couldn't find anything. So
13 in theory it should work, but we, we
14 have no test.
15 [Marta pages through notebook.] [80s]

16 **Marta:** Remember what values we
17 ended up using, in terms of the weights?
18 I think we started with like a hundred
19 grams, and then we went up to-
20 **S3:** Two hundred. Yup.
21 Marta: Did we ever not use, did we not
22 use the big, one kilogram at all?
23 **S3:** No. It was too fast. [10s]
24 **Marta:** We had four hundred in the
25 cart, right?
26 **S3:** Yes. No. We changed it to three
27 hundred. If you had three, and then you
28 would take off two and leave one
29 hundred.
30 **Marta:** I think one of those two was a
31 two hundred. Cause it was a big fat one,
32 and then it had like two regular ones.
33 **S3:** I don't know. [42s]
34 **Marta:** And like the other problem was
35 that when like say for example we had
36 um we had it moving, but it was moving
37 very slowly and then if we added weight
38 it would just stop. Cause it wasn't
39 enough like.
40 **S4:** Yeah, it would kind of like stop
41 either way.
42 **Marta:** And then, but when we did.
43 Cause remember towards the end like
44 we did a really big weight to get it really
45 moving and then we took it off, like
46 halfway in the middle of the air. But it
47 was like impossible because it's not
48 enough length to really measure the
49 effect of anything.
50 **S3:** We'd have to really like have that
51 thing really high in order to [inaudible]
52 that. [On phone] Hey. Wake up. You
53 have class. [inaudible] in thirty minutes.
54 Bye. [Hangs up] [inaudible]. [23s]
55 **S4:** Wait no, but didn't we come to the
56 conclusion that when you put more
57 weight on the cart, you were testing the-
58 **S3:** Mass affected it.

This episode looks quite different than the previous episode, perhaps because Marta and her group are facing a problem that they cannot solve individually. In this episode, Marta both asked questions (19, 24, 27) and posed her own explanations to the group (19-21, 32-35, 45-52), and the other students also had a chance to present their explanations about the details of their experiment and what it demonstrated. When they were explaining their ideas or asking questions, the students frequently made eye contact with one or both of the other students. Last, while exchanges mainly occurred between just two people (S3/S4 in 1-14, Marta/S3 in 17-36, S3/S4 in 59-63), the partnerings vary, and there was a sense that nonspeakers were still monitoring the conversation, because information was not repeated and exchanges built on previous exchanges.

In comparison to the previous episode, the participants in this episode had more equitable roles. Their actions were aligned with the expectations that each person could and should contribute something, as evidenced by the multiple conversational turns of each person and the fact that they should all pay attention to the conversation, even when not actively participating. The group also displayed a different understanding of what "working together" means, that collaborating involves contributing to the discussion by forwarding ideas but also through active listening to other group members. Further, this group showed that they valued collaborative participation. When faced with a difficult problem, they framed the activity as one that involved the contributions of all members of the group rather than the appeal to an authority figure.

Discussion and Implications

Establishing a community of learners has been a part of the successful reform at our institution, increasing the odds of success, the conceptual learning, and the ways students work with each other (Brewe, et al., 2009, 2010a, 2010b). Learning more about how individuals participate in this community and how this participation changes as their class progresses can help us design instructional environments that better support these changes. In Marta's case, her role in the small group changed from one of a knowledge source to a co-contributor of knowledge and her framing of learning in a group is this class changed from one where she works alongside other students to one where she can use and build on others' ideas. This change in participation can be used to further enhance students' sense of community and, ultimately, their persistence within physics.

This, and future related research, has important local and global implications. First, by studying how individuals change their participation, we provide evidence that is consistent with the participationist perspective on learning and further advocate its role in theories of learning. Second, we provide examples of how changing students' participation can have valuable outcomes, such as enhanced retention within introductory physics.

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