Inquiry in cultural context: Interactive Engagement Among Brazilian Physics Students

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Abstract:
We examine the impact of bringing instructional methods developed for Introductory Physics (IP) courses in the U.S. to a Brazilian university with high failure rates and low retention in IP. Using participant observation, interviews, and questionnaires, we investigate the influence of cultural context on the effectiveness of the imported teaching approaches. We describe student responses to instructional approaches that were designed to change their epistemologies, interactions, and sense of responsibility for learning.

Overview

This study focus on STEM college students enrolled in Introductory Physics at the Federal University of Juiz de Fora (UFJF), Brazil. Brazilian students start college after completing at least three years of test-preparation style physics instruction often arriving at college ill prepared for inquiry-based approaches to science learning.

We investigated how students' learning is shaped by years of test preparation and a broad but superficial secondary curriculum that requires memorization of isolated facts, discourages interaction between students, and lacks explicit connections between the physics curriculum and the physical world.

Our work was influenced by situative learning theories, where learning is regarded as becoming a participant in a community of practice. Newcomers are introduced to the community through legitimate peripheral participation, gradually becoming capable of full participation. In this view, science learning activities should be modeled after the work of scientist, differences between being a student and being a scientist should be minimized.

In this work, we wanted to know how students differed from experts, how they believed that their physics learning reflected on nature, how they were responding to the expectations that they participate more actively in their learning, and how the interactions between students had been influenced by the instructional methods.

Background

Despite Brazil's level of productivity in the sciences, Brazilian science education indicators are among the worst worldwide (UNESCO Institute for Statistics 2004).

At the undergraduate level, these problem are reflected by underprepared students who are not able to take full advantage of their higher education opportunity. A number of students who attend classes and dedicate substantial effort fail, repeat, and eventually drop out of courses. After reaching the limitations of rote memorization, these students are unable to meet course requirements.

The way students view learning goals, physics knowledge, and their roles and responsibilities, contributes to high failure rates. Students lack experience evaluating or planning their own learning, have little idea about how to approach study other than by repetition, maintain parallel understandings of how the world works for test responses and their own understandings, and report little discussion of science among peers.

As one UFJF graduate, now a high-school Physics teacher said:

When I think of a situation, I usually think of it in three different ways: the one I was taught in college, which is too hard for my students; the watered down version of it, which I teach; and the real one.

Methodology

Our goal was to better understanding of how student approaches to science and peer interactions changed during their IP course, and how students responded to unfamiliar strategies to learning, approached science, and interacted.

We carried out this study in one of the first semesters after introducing Physics education innovations adopted from the U.S. literature to the UFJF Introductory Physics Course. We used participant observation, interviews, and surveys to find out about characteristics of the student culture and experience that facilitate or complicate student transitions to a collaborative and interactive approach to learning.

During the first semester, one of the authors observed classes and group activities. During the second semester, a different author participated in the class and documented details of group interactions.

We also conducted several informal conversations and interviews with former and current students and videotaped group activities.

Finally, an anonymous questionnaire asked students to indicate which resources (books, colleagues, etc.) were most useful to them.

We also took advantage of informal opportunities such as office hours and conversations after class to find out about how student approaches to science were changing through participation in the course.

We were specifically interested in how the instructional changes influenced three key characteristics:

1. How students change from relying on authority to relying on empirical evidence;
2. How students responded to a requirement of active participation and ownership of their learning;
3. How students engaged in dialogue with their peers after years of isolated study.

Nature versus Authority

In a secondary environment focused on testing and memorizing students shift their priorities from a focus on nature to a focus on the teacher. Instructors become the ultimate authority and questioning is undervalued.

Students can't always relate what their studies with the real world, leading to coexisting models, one fitting what is expected in school and another fitting their beliefs. Many physics textbooks illustrate concepts using contrived examples. In those activities the successful student must ignore common sense when solving a problem. This encourages successful students to maintain two independent contradictory worldviews, ignoring what they know when working on school assignments.

When students spontaneously test their ideas against nature, we can infer that they believe in the connection between what they studying and the world, and that they are changing their worldview in response to what they learn. In contrast, when students aim to predict what the professor thinks, this may not be true.

Despite some apparent improvement, we found evidence that some students were maintaining separate worldviews. In the example below, three students discuss a problem involving a person pushing a block. After struggling with the problem one student noticed something wrong with the group's free body diagram: the force of friction seemed to be pointing in the wrong direction. To explain, he cited as everyday experience, asking his peers which direction their feet would slide when pushing a large object. With the incorrect drawing in front of her, another student claimed that her feet would slide toward an object she pushes. In the classroom she ignored her real life experience when it was inconsistent with the diagram in front of her.

> Student A: Get up and push the wall.
> Student B: What?
> Student A: Get up and push the wall.
> Student A: Your feet will do this.
> (He presses his hand against the wall, demonstrating the motion of the foot away from the wall. Nobody in the group gets to try his "experiment.")
> [...]
> A: So, if you're pushing, your foot, its tendency is to push toward the back. So, friction will do this, look. (Draws the direction of the friction and the motion on the whiteboard.)
> C: So, that is what I meant.
> A: So, the force from your foot points toward here. (Shows friction in a direction opposed to the motion.)
> C: No, your foot is making a forward force. It will push forward.

Finally, the group decides to call in the TA for help with this inconsistency, instead of trying themselves.

On several occasions, we have observed the transition from school focus to nature focus as an isolated moment. In most cases, testing ideas in nature is something that students either do consistently or never.

Engagement and Responsibility

Effective participation in communities of practice requires that students assume an active role in their learning, taking personal responsibility for the learning process. This is reflected in a range of changes to student work including making choices and developing strategies for their own learning and evaluating new information.

We look for evidence that students are considering the content of the course, comparing the content with the physical world, and trying to make sense of the material. A stronger sense of responsibility is evident when students continue working after class or meet outside class to discuss the material.

In the example above, about friction, the group waved down a TA for help resolving their disagreement. Ultimately confirmation from the instructor was needed to resolve contradictions between group members.

Students must also be ready to risk making mistakes in order to learn from them. This is difficult for students who have been subjected to years of rote learning and testing. During one activity a UFJF IP student made the following remark:

> It's better to not put anything and say we didn't do it than to put (an answer) and later have to erase it and do it again. It's better not to do it.

students were assigned roles of leaders, scribes and skeptics to ensure active discussion but at times it seemed that some were not comfortable with debate. In several groups working on tutorials, skeptics questioned inconsistencies but when inconsistencies became evident, groups would turn to the instructors for resolution rather than continue discussion.

In one case, after a very calm disagreement, everyone in one group put their pencils down, stopped talking, and and began energetically flagging down the TA:

A: Enlighten us, because things are getting ugly.
B: It's practically a fistfight here.

We have not seen this kind of conflict avoidance reported by American researchers using the same materials, and may be related to the Brazilian cultural tendency to avoid open disagreement. The Brazilian

Students in group activities focused on what the professor was looking for. When they compared their opinions, rather than talk about what they think or what they believe, they would refer to what they planned to put on their answer sheets or what they would put on exams given a similar question. After writing on the board many useless and unrelated equations and diagrams, a student said:

If you forget that on a test, it's over.

Students showed an increased commitment to their work and responsibility for their own learning, even when the professor was not present. On several occasions, students stayed to discuss their work long after the class was over, often staying in the classroom for as much as 45 minutes after the end of the class time, at the expense of their lunch breaks.

However, in one semester, the professor attempted an experiment. Given the importance of group work, he had students working in groups during the midterm exam. The exam was divided into two parts: a context-rich problem, to be completed in group, and specific questions about the solution to the problem, to be answered individually. Before the exam, students were excited about doing it in group, but when the midterm was over it became clear that this was a failure. Students claimed doing worse than they would have individually, even though they thought collaborations were helpful during classes. Under pressure, students abandoned the process of scientific discussion. This calls into question the confidence students have in their collaborative techniques when they need the job done.

Peer Interaction

From the student point of view, the presence of group work is the most obvious difference between IP and their other courses. While many components of the course are new to them and many of the course objectives differ from other introductory physics classes, students were most aware of the group component, and often referred to the IP instructional approaches as "the collaborative method." When asked, students usually talked about working in groups. This is not surprising, since only 1 out of 42 students in the first class reported doing any group work in school.

The curriculum materials were designed with U.S. students in mind, students with much more experience learning together. There was a concern that Brazilian students might have difficulty with or object to working together. But students at UFJF were very receptive to group assignments. In the U.S. educators describe common complaints of students who prefer individual assignments. At UFJF few students claimed that they preferred to work alone.

Some students spoke with the professor privately about concerns related to the group activities. Issues raised during office hours related to problems with individual group members whose participation level was regarded by peers as inadequate. When students talked about these problems, they revealed that they recognized the potential value of a more productive group discussion. On several occasions students reported a connection between the productivity of their group and how well they learned. One student visited the professor after a member of his group was transferred to a different group. He was concerned that the transfered member was key to the interactions, and that without him the dialogue had become less productive.

I know that I am not going to learn well if our group does not discuss well.

Other students have expressed interest in being placed in the groups that they regarded as more productive.

Assigning roles for group members helped students in developing effective ways of working together. Students had most difficulties with the role of the skeptic. In one semester, the professor experimented with not assigning roles. Several weeks into the semester, the professor noted that a group was having trouble making productive use of their discussion time. He introduced the idea of assigning roles, and participated in the group discussion for about 15 minutes to exemplify the role of the skeptic. A week later, the group spontaneously approached the professor after class to say that the use of roles had improved their interaction. One student said the following.

> Before having the roles, we would each work separately, and would compare our conclusions at the end. Often, when I wanted to compare my results with someone else, the other people in the group would be working on other parts of the activity, and I would just give up

discussing and keep going on. With the note taker and the skeptics, everybody discussed, and we found out that we were not really understanding some concepts.

Final remarks

Throughout the course, we saw improvements in the three areas of student approaches to learning that we investigated.

1. Empirical evidence vs. authority.
We found that an increasing number of students approached their learning more scientifically, clearly showing that they thought of the material within the context of the natural world, instead of maintaining separate worldviews for school and real life. We also witnessed moments of discovery, in which students made their first connection between physics and the world.

2. Legitimate participation.
Students adapted well to the requirement that they take a more active approach to their learning, but many continued to regard their learning process as a matter of retaining information. Initially students had very little experience in questioning and critical thinking, but later most were able to approach questions critically. They generally accepted their new responsibilities in the learning process, but continued to evaluate their own success in limited ways. Instead of viewing their improved abilities to participate in group as an achievement on its own, they saw it as a vehicle for higher test scores. Instead of thinking about how their understanding changed, many students were interested in how their ability to solve problem improved.

3. Peer interaction.

Students welcomed the opportunity to work in groups and to work on activities that allowed them to apply the concepts they had learned. They gained proficiency in communicating complex ideas and using conceptual tools. Contrary to Feynman's findings in the 1950s, UFJF students were willing to expose their doubts to peers. Their main difficulties in effective collaborative work were in criticizing peers and acting as skeptics. The fact that students continued to study together in subsequent semesters indicates that IP helped them become both more independent and more collaborative during the course.