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FORUM

Gender, identity and culture in learning physics

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Abstract Student engagement in science, as defined by Iva Gurgel, Mauricio Pietrocola, and Graciella Watanabe, is of great importance because a student's perceived compatibility with science learning is highly influenced by personal identities, or how students see themselves in relations to the world. This can greatly impact their learning experiences. In this forum, I build on the work of Gurgel, Pietrocola, and Watanabe by exploring the relationships between engagement in physics and gender, and by looking at the expansive nature of the concept of culture. I expand the conversation by investigating ways in which learning science has impacted my own identity/worldview, particularly how it affects my personal teaching and learning experiences. I focus the conversation around the relationship between gender and the experience of learning science to further the dialogue concerning identity and how it impacts engagement in science. I also look at the role of didactic transposition in the perceived disconnect with science. I reveal my experiences and analysis through a personal narrative.

Keywords Identity · Culture · Science education · Women in physics

Gender and the cultural collide

In the work done by Gurgel, Pietrocola, and Watanabe the aspect of cultural identity focused on is a student's national cultural identity, Brazilian. As was discussed in their work, national identity is just one of the many aspects of an individual. Other aspects,

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including race and gender, are also essential when thinking about a person's identity with respect to learning science. Historically, in my own experience as a female student of physics, gender was an important part of who I was within every classroom experience and how I viewed myself within the context of learning science.

As a woman studying Physics at the college level I had my own experience with cultural disconnect as it related to my gender. My decision to study physics in college was the result of positive experience I had as a high school math and science student, the enjoyment I experienced when problem solving and the success I had in STEM related courses. One of very few women in my formal science classes, I studied physics surrounded by male teachers and male students who had very concrete goals. They wished to be engineers, work in a lab or hoped to continue studying science in graduate school. I was uncertain of my own path upon entering college, but soon realized the reality of the gender disparity in my classes. Though not treated differently, my own perception of self was influenced by the very visible lack of female representation in the faculty and student body. In considering what it means to be a college student studying physics, a common trait shared by many of the constituents was gender. Though not a requirement for entry into the physics major, being male seemed to be an aspect shared by many members of the group and therefore appeared to define it. As a woman I often felt that I had overcome the requirement and was able to assimilate into the culture to become "one of the guys". This idea of the individual informing the collective was very much part of my own reality and because being male appeared to be a trait that defined physics majors I felt that I had overcome the label.

As suggested by Anthony Giddens (1991) and discussed by Gurgel, Pietrocola, and Watanabe, the group exists because of the individuals that make up the collective. The individuals that comprise a certain subgroup define the characteristics of what it means to be a participant. The group itself becomes defined by such traits that are then assumed for all other constituents. These traits would not exist, nor would the group, if the individual did not experience uniqueness. Gurgel, Pietrocola, and Watanabe refer to this notion of assuming traits about an individual based on a group that he or she may or may not identify with as labeling. I experienced the impact of such labels by acquiring the stigmas associated with a male dominated field. Labeling is also prevalent when considering the public view of science and the notion of what it means to enjoy or appreciate it. When I tell people that I teach physics the response is normally some variation on "Oh wow, physics is difficult" or "I am not good at science". The individual is looking at science defined by a particular label and then distances himself or herself from it.

As Gurgel, Pietrocola, and Watanabe discussed in their study, the conflict of belonging impacts the identity constructed with respect to one's own uniqueness amongst a group defined by a character trait that you do not possess. The authors reference the work done by Nancy Brickhouse (1994) who makes an important point that we must stop considering that there is something wrong with a girl's ability to learn science and should instead examine what is wrong with how science is being taught. Almost as important as how science is taught, is what science is being taught and with what purpose. Brickhouse (1994) notes that the achievement differences that appear in boys and girls in the physical sciences as early as 9 years old increase in other sciences, as they get older. Conceptualizing science as a reductive body of knowledge and practices and learning as transmission of such knowledge and practices in a bounded classroom may only perpetuate the cycle of marginalizing women from the field of science. By expanding the notion of science as culture we can attend to identity development through implicit and explicit structures that are produced and enacted inside and outside the physical boundaries of the classroom walls. Such structures shape how we perceived our relationship to science through our identities. An ever-present rift in the relationship between science and identity contributes to the lack of women in science majors and science careers.

Transformations

In my first 2 years as a science teacher I found it fascinating to see which students elected to take physics classes and which students abstained. My first physics class had only two female members out of a roster of 25. The noticeably disproportionate gender representation was striking to me. Looking back on this experience it is interesting that I was so astonished by this disparity. My experience in the college physics classes I attended as a student supported the stereotype, but my personal perspective rejected this notion.

My experiences as a college physics major proved to be transformative. Spending long hours in the science building with my fellow physics majors studying for exams and writing up detailed lab reports resulted in a strong sense of camaraderie. For me, learning physics and being part of the stresses, successes, and mutual foci of my peer group led to what Randall Collins (2004) would refer to as emotional entrainment. By being a member in a social network organized around the learning of physics, my understanding of the structures that defined its membership transformed. Collins' (2004) Interaction Ritual Theory describes the connection between an individual's lived experiences and his/her understanding of the structures and rituals within the social group in which the experience was shared. This theory helps to explain the individual | collective as a dialectical relationship, where each could not exist without the other and where each is a constituent of the other. My understanding of what it meant to be a member of the group was refocused around the experiences I had within it and led to a transformation in what it meant to me to be a student of physics. I no longer viewed being male as a trait one needed in order to be successful in science. I had spent 4 years working toward a degree in physics and at some point along the way it became part of my identity. It was not until I reflected back on my experience that I was able to identify how my view had changed.

The transformation I experienced aligns with the work done by Gurgel, Pietrocola, and Watanabe where in the relationship between cultural identity (being Brazilian) and engagement in science is addressed. The views of participants within the study evolved and were further informed through the implementation of three interventions. Looking at their study through a lens of ontological authenticity, as defined by Egon Guba and Yvonna Lincoln (1989), the participants as well as those who conducted the research went through a re-consideration of their own thinking as a result of the shared research experiences. Both the researchers and the participants benefited from these shared experiences and their work has the potential to further benefit the institution. The goal of the research was to examine the relationship between identity and learning science, which I have expanded upon using my own teaching and learning experiences both of which had resulted in transformations in understanding the relationship between identities and learning physics.

If we expand our view of science as culture we can better understand the ways in which our lived experiences contribute to our meaning making and discovery. It can also provide an opportunity to look at science as something that we all engage in through being in the world and not as an established community of elite that is narrowly defined.

Science as culture

In their research, Gurgel, Pietrocola, and Watanabe use culture to describe the students shared national origin and the science culture of the school to be a set of information and formal language transposed from the science community. In this sense the cultural identities of the students are strictly bound by notions of what it means to be Brazilian, and the culture of science in school is strictly bound by a specific set of science principles and ideas. According to William Sewell's theory of culture (2005), being "strictly bound" means having thick coherence of meanings. For example, being a scientist is conceptualized by the majority as being white and male and therefore has, "thick coherence" of meanings. Being female or of another race is often ignored or discarded as an anomaly because the overriding concept of culture does not allow for multiple meanings, let alone contradictory ones. The authors push back on the collision of these two cultures and begin the conversation of the overlap between them. Looking at different ways in which culture can be viewed and theorized provides an additional perspective to their work. If we consider science to be culture, then we must not only look at the interactions between science and identity but also the way our lived experiences inform our identity within the culture of science.

Sewell's theory of culture (2005) looks at culture as knowledge production and discusses it as having thin coherence and ever-present contradictions. In the work done by Gurgel, Pietrocola, and Watanabe, the aspect of science production is first examined in the study through a survey that provided information about the students' views of nationality in relation to science. The survey also asked students to generate a list of famous scientists, which provided insights into who is seen as a scientist and what makes science part of their identity.

The idea of being defined as a scientist emphasizes the view that science is a subject that is studied by a specific sub-group of individuals. Based on general perspectives held and presented in society and the media, this sub-group is selective. Even the image of a scientist being a white male with a white lab coat, implies certain physical attributes that a scientist possesses. This idea can be conceptualized by considering the dialectical relationship between agency and structure, where in each of the constituents does not exist without the other. Enacting one's agency can often passively reinforce the structures by accepting well-defined boundaries of what it means to be a scientist and acting accordingly. This view also reinforces the existence of a strictly bound "scientific community" with schemas and practice that are not representative of all people. If we instead look at science as culture with structures, schemas and ever-present contradictions, we can bring to light a new understanding. The view that, culture is the [re]production of knowledge, as defined in Sewell's theory of culture (2005), culture can only be produced from existing structures, so the reproduction of knowledge/culture will always have some resemblance to the prior structure. Viewing science as culture, one's identity within the context of a science classroom should overlap with other aspects of self in identity formation. In trying to link one's national culture with science, the disconnection is a result of a set of perceived criteria of what it means to be a scientist and who does science. The students who participated in the study, view the act of participating in science as being "beyond the perceived norm of their own cultural abilities" (Gurgel, Pietrocola, and Watanabe 2015). This does not have to be the case, science should not exist as an exclusive group of individuals and we must explore the perpetuation of this notion further.

Falling out of love with science: through didactic transposition

In discussing the conflict between the students' perceptions of Brazilian culture and science, I am reminded of my own experiences as a student in a large suburban public high school in New York. Although not true for everyone, learning science at a young age was both fun and natural for me. During science lessons my classmates and I were often asked to question, explore and experiment with things that were both new and familiar to us. We were asked to express our understanding of how and why things act the way that they do and received validation for attempting to explain the world around us. When we are children we perform science experiments on our own and observe what happens around us with wide eyes, touchy hands, and no fear of failure. Motivated by our own desires to understand the way the world works, we test gravity and the limits of the frictional force before even learning to walk. A young child can push something off the table and seeing it fall to the ground, try this act a second time. The confirmation that things drop to the ground can excite the child to continue in this process knowing what the outcome will be based on previous experience. These acts of exploration are science.

As we grow older the structure of science classes becomes more rigid and the courses become abstract and decontextualized. Science is no longer an expression of an individual's own curiosity, but a set of pre-produced concepts didactically transposed into a core curriculum. The textbooks and the tests highlight information that was discovered, equations, diagrams and symbols that have been created to represent the "beauty" of the natural world. Students are expected to answer questions and apply understanding based on abstract principals that many times they have been asked to accept as truth. Even though a teacher might say they support multiple perspectives or ways of doing science, it would be more difficult to assess students in this way. This is an important aspect of the axiology of the teacher, the school and the school system where decontextualized canonical versions of science, as represented in standards, are privileged over contextually meaningful sciences experienced in people's everyday lives. This method of science consumption, as apposed to science production, creates opportunities for the kind of identity disassociation that was discussed by Gurgel, Pietrocola, and Watanabe with respect to one's cultural identity as it relates to learning physics.

In my own classroom a student's engagement in science comes in all varieties. It is easier to teach someone how to do something in a physics class than it is to teach them why they are doing it. Too often students are so concerned with answering a question correctly that they neglect completely why exactly the answer is even significant. This is not their fault. The process of asking questions and searching for a correct answer is consistently modeled for students throughout their learning careers. Students are more engaged in learning when they are motivated by a personal desire to learn. When my students perform a lab experiment we identify the question that we are attempting to answer, the procedures and the analysis techniques. Once the lab is complete students will ask if their answer is correct. They seem to feel that a question is never asked that does not have a predetermined answer, but this is simply not true. Due to rigid state curriculum and pre-established assessment tools, I am often forced to stick to formal labs that do not provide room for inquiry but are a reproduction of the idea that the lab has a set solution that the students are trying to figure out. We ask questions all the time we can't answer for certain and therein lies an opportunity for further exploration. A multiple-choice exam for example, does not give students an opportunity to express their own desires to question and explore. Teachers are very often bound to state exams but teaching with the ultimate goal of getting students to pass a required exam tells students the answer is more important than the path to discovery.

The perception of science as truth, and facts that are discovered by members of an elite group ultimately lead to the view that scientists must have very specific traits and those who do not possess these traits are excluded. During the intervention in the study conducted by Gurgel, Pietrocola, and Watanabe when the students were brought to a lab with Brazilian scientists and interacted with a Brazilian researcher the students were exposed to the idea that science is not sets of laws and rules but instead the search for unanswered questions (Gurgel, Pietrocola, and Watanabe 2015). The experiences that researchers have are comprised of just that, asking questions and searching for answers. After their visit to the lab some students "expressed astonishment" that their own nation could produce such a lab and sparked curiosity as to where funding for the lab came from. Whatever difficulties they had in seeing themselves as "scientists" is a reproduction of the idea that to be a scientist one must work in a lab, which is not the case. But then again, one should not have to fall into a classification to appreciate certain experiences of questing and discovery.

Yves Chavallard's Theory of Didactic Transposition (1991) has implications on culture production and identity formation. The relationship between the teacher, the student and the taught knowledge is of great importance within all teaching and learning environments especially considering knowledge taught in schools. Didactic transposition is how knowledge/culture is produced in the life of a scientist and how it becomes represented in textbooks and ultimately how the teacher enacts the culture/knowledge in her classroom Often culture of science is comprised of sets of truths transposed into the classroom in ways that contribute to disconnected feelings of students toward science in schools. Knowledge presented in schools can be considered a series of ideas generated outside of the classroom that are transposed and evolved into scholarly knowledge, which has been informed by outside sources. As a High School physics teacher in New York City, I see the impacts of this transposition. Although I try to engage students in problem solving that is relevant to their own lives, I have seen the impacts of mandated science standards and assessment which prove to be key contributors to feelings of disconnection between students and science. Through my experience as a NYC physics teacher it is evident that curriculum is considered to be what is taught, which individuals outside of the specific learning experience inform. The courses taught in schools are based on a set of State standards that the students are expected to meet. In physics much of this is algebraic problem solving, laws, accepted theories of how the world works and application of these theories. Although it is not the only lessons learned in a particular class period it is the basis for what goes on within a classroom.

Learning should be purposefully meaningful, contextual, and enacted in ways that transform the real world for social and nature's benefits (Vianna and Stetsenko 2011) Inquiry based learning is one example of a way to counteract the view of science as transposed truths. Learning through inquiry provides students with opportunities to participate in discovery and inform their own meaning making. As discussed by Heather Banchi and Randy Bell (2008), there are many levels of inquiry but what is most essential is providing students with opportunities to explore their own questions, design their own experiments, and pursue their own ideas. Being in the world provides a great opportunity for learning to happen and through inquiry the teacher, student and what is taught switch roles throughout the learning process. When students can relate to the ideas being explored, and contribute to all aspects of understanding, they are more engaged and more inclined to ask questions and participate in further discussions. This is an act of pushing back on the knowledge that is didactically transposed, enacting agency, and informing his or her own knowledge [re]production.

This transposition of knowledge from teacher to student with no opportunity for students to repurpose the knowledge structures contributes to cultural disconnection or distancing. A culture that seemingly belongs to the teacher is often expressed as "too hard" or "pointless" within the classroom. Developing lessons in order to appeal to student interests and engaging students through real world examples is a way to share the schemas and practices within the culture of science. These practices and schemas may not transcend boundaries in the students' eyes and in turn appear to be incompatible with their own identity. I often ask my students to share how physics relates to their own lived experiences and although I receive valuable responses I am still tied to a set of information that must be taught. Students can easily generate a long list of physical forces they experience throughout their day and expand the conversation into a deeper understanding of the abstract concept of actions and reactions. Students eagerly respond to the idea of decision-making based on anticipated outcomes but then become overwhelmed with equations, which they view as structures of science and not as representations of the same relationships they so eagerly discussed. The formalities of the equations are constructions of the scientific community and can be viewed by students as incompatible with their own identities. Since, according to Sewell's (2005) concept of structure, new structures can only be reproduced from existing ones, students find it difficult to further develop ideas without the structural foundation needed to do so. Equations and laws are part of the strictly bound science community. Without the ability to permeate this boundary, develop a structural foundation, or see oneself as part of a science culture, a disconnection is an inevitable result.

In order to begin to move beyond the disconnection, we must help students, teachers, and society re-define their strict (i.e., narrow) views of science and what it means to be a scientist. Conceptualizing science as culture can illuminate ways for us to begin to permeate the walls that confine an elite science community and help teachers to not reinforce the strict idea of who does science. This view of science as culture could help to realign the axiology of a system that promotes didactically transposed curricula that alienate so many of our students.

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