

Obscuring Power Structures in the Physics Classroom: Implications for Student Engagement and Physics Identity Development

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Abstract. Many students are disempowered in physics classes finding them to be more difficult, unpleasant, narrow, and masculine when compared to other subjects. Such disempowerment can lead students to limit their engagement. This study explores how physics teachers can help students engage with the material and develop their physics identities by obscuring traditional classroom hierarchies. Employing a positionality lens on case studies of four high school physics teachers, we coded teachers' behavioral cues that contributed to the relational structure in the classroom. Our findings suggest that teachers' physical cues (space and hierarchical stance occupied), structural cues (dynamic nature of the classroom allowing alternating roles), contextual cues (including students' thoughts and experiences), and social cues (obscuring traditional boundaries between teacher and student) affect the social distance between the teacher, students, and content. This social distance can moderate students' level of engagement and ultimately their physics identity development.

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INTRODUCTION

Not only has physics fallen behind the overall growth rate of the undergraduate population but the field continues to face representation issues in terms of female and under-represented minority participation [1,2]. Together with diversity issues, science educators continually face the challenge of countering declining science interests among students as they traverse educational levels [3]. One of the most difficult tasks faced by science educators is engaging students in their learning in personally meaningful ways that maintains/raises their physics related self-perceptions. Compared to other courses, it has been found that physics classes are perceived by students to be more difficult than other subjects, more limiting in terms of sharing ideas, more unpleasant in general, and more appropriate for males [4, 5]. Such perceptions may exacerbate discomfort and disempowerment, resulting in students being more reticent to communicate and more likely to rely on rote learning strategies [6], which provide comfort and cognitive ease. A difficult problem is thus posited for practices that we advocate as optimal for learning science (e.g. active learning) because they may lead to some students disconnecting further because of the risk associated; particularly if they have little prior experience dealing with such risk. We need to be more nuanced in our thinking about reform because of “how

risky and uncertain a new kind of science education might be” [4], particularly for students who are already marginalized. Thus, the broad challenge that guides much of the current work is: *In the face of challenging and often threatening material, how can physics teachers scaffold students to meaningfully engage in learning physics without adversely affecting their physics-related self-perception or physics identity?*

POSITIONALITY AS A THEORETICAL LENS

We define positionality in the physics class as the social location and role taken up by the teacher and students with respect to each other and the content as a result of the relationships/structures conveyed in the class [7]. This lens helps us understand power-based structures in a physics class that influence the level of engagement between the teacher, students, and content [8] and the subsequent impact on physics identity development. Physics identity is conceptualized as how students see themselves in relation to physics based upon both their perceptions of physics and their negotiation and navigation of everyday experiences with physics [9]. These experiences largely occur within science/physics classes since most students have little experience with physics outside of the classroom. The broader goal of this work is to begin to understand how physics teachers enact strategies that

engage students in their physics learning while developing their physics identity. Our theoretical conceptualization of physics identity can be found in our prior work [10].

METHODOLOGY

This study draws on data from an NSF-funded project which is a qualitative explanatory follow-up to a large-scale quantitative study ($n=3829$). The quantitative study identified high school physics experiences that positively affect students' physics identities and persistence in physics [10]. These experiences include: focus on conceptual understanding ($p<0.001$), students teaching classmates ($p<0.001$), students making comments / answering questions ($p<0.001$), discussion of currently-relevant science ($p<0.001$), discussion of benefits of being a scientist ($p<0.001$), labs that address students' real-world beliefs ($p<0.001$), and for females, discussion of the under-representation of women ($p<0.01$). A list of teachers who fulfilled a majority of the seven criteria and were identified by a student who had developed a physics identity (from the quantitative study) was generated. The four teachers recruited satisfied five or more of the eight sampling criteria. Although all four teachers are middle-aged white men, research has found that it is not the gender/race of the teacher that matters per se but the relationship those teachers have with students, even females and under-represented minorities [11].

Dr. D taught three physics classes at a large public school (more than 2000 students) in Texas where 66% of the students are on free and reduced lunch. This proportion is much higher than the national average of 39%. Almost all of Dr. D's students (95%) were of Hispanic ethnicity and a little over a third were female (36%). Dr. D has a BS in physics (and a PhD in another science – not specified for anonymity) and has taught high school physics for 15 years. He satisfied seven of the eight sampling criteria.

Mr. S taught three physics classes at a medium-sized public school (1000-2000 students) in South Carolina. He taught a few students from a minority background (9%; two Black and three Hispanic students) and slightly less than half of his students were female (43%). Mr. S has a BS in a science discipline, MS in science education, and has taught high school physics for 14 years. He satisfied all eight criteria.

Dr. P taught four physics classes at a small private school (less than 1000 students) in New Jersey. Almost all of the students (92%) at his school are White. There was only one student from an under-represented minority (Hispanic) in his classes while

the majority of his students (64%) were female. Dr. P has a BS, MS, and PhD in Engineering and has taught high school physics for 13 years. He satisfied six of the eight sampling criteria.

Mr. B taught two physics classes at a medium-sized public school (1000-2000 students) in South Carolina. He taught a few students from an under-represented minority background (12.5%; four Black American and one Hispanic student) and a quarter of his students were female (25%). Mr. B has a BS in physics, an MEd in Science, and has taught high school physics for 28 years. He satisfied five of the eight sampling criteria.

Data collected included video recordings (one week with observation as well as subsequent video recorded by teachers); observer field notes for one week of observation; two interviews with each teacher; lessons, materials, and other resources; student work/grades; student surveys; and interviews with students ($n=29$, 7-8 per teacher). Students were selected for interviews based on their self-reported identification with physics (both high and low cases) as well as deliberation with their teacher and observations of their behavior in class. The interviewed students were purposefully selected to include underrepresented groups. Of the 29 selected students, 18 are female, one is black and 10 are of Hispanic ethnicity. We used a constant comparative analysis, first open coding for categories around teacher positionality and then axial coding between categories and evidence of student engagement and physics identity development.

RESULTS

Differences in Student Engagement

Our analysis revealed significant differences between the teachers in terms of the level of student engagement with the class and the material. Students in Mr. S's and Dr. D's classes were more broadly participatory than students in Mr. B's and Dr. P's classes, where more select students' voices were heard repeatedly. To triangulate these observations, the survey data ($n=146$) was analyzed constructing a regression with the teacher effect predicting student participation (answering questions and making comments) while controlling for science confidence, class size, and physics grades. Figure 1 exhibits the difference in student participation found across the teachers where Dr. P is the regression "baseline" to which the other three teachers are compared. These results confirmed prior differences observed. Other evidence of student engagement in Mr. S's and Dr. D's classes includes student interview excerpts such as:

D1: "...I put myself into it, I like really want to try." (Hispanic F)

S1: "I like when we have like, like discussions with the whole class that everybody like is kind of just like throwing out like their things and it's just like a big discussion on whatever we're talking about...it seems kind of like it's like not something about class but just like a normal everyday thing and then you kind of like, like you like understanding it and then it's easier to like relate it to you..." (White F)

Using a positionality lens, we examined how teacher positionality could lend insight into the differences we observed across teachers.

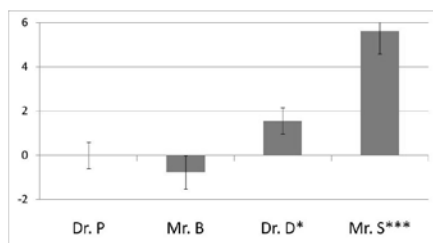


FIGURE 1. Difference in participation (answering questions and making comments) across teachers controlling for science confidence, physics grades, and class size (* $p < 0.05$; *** $p < 0.001$)

Positionality Codes

Our coding, both from the video and interview data, revealed four main categories for teacher's behavioral cues related to positionality. These were:

- Physical cues – physical proximity or hierarchical stance with respect to students
- Structural cues – taking on different roles, opportunities for students to take on different roles
- Contextual cues – meaningfully incorporating students' thoughts and contexts
- Social cues – obscuring social boundaries between teacher and student

These cues, related to the teacher positioning in class, had strong implications for student engagement and physics identity development.

Positionality, Student Engagement, and Physics Identity Development

Mr. S and Dr. D exhibited the most codes that represented a narrowing of the social distance, i.e. positioning, between teacher and student. Mr. S exhibited the most instances of contextual cues linking the material to relevant contexts. There was a spectrum of instances/activities representing contextual cues including the discussion of popular TV shows with scientists, discussion of gender issues in physics,

building paper mache models of the eye, and several others. Mr. S, as well as Dr. D, exhibited many structural cues that were manifested in their activity structure, use of different types of activities during a single class period, and in the case of Mr. S, organizing his classroom space in different ways. For example, students in Mr. S and Dr. D's classes commented:

S2: "...he picks like us randomly so that it's not necessarily you have to raise your hand all the time just to put in like input...we go around the class so that way everyone has like a chance to talk..." (Black F)

D2: "I like the way he like makes us get up and get involved with it because it like makes you think about it and it makes you like understand more about it because if it was just about bookwork then sometimes it confuses you..." (Hispanic F)

Both Mr. S and Dr. D showed greater non-hierarchical physical proximity to students, such as situating themselves in seats near students or moving around to become nearer to different students when discussing topics and introducing material rather than standing at the front with students facing them. Dr. D, by far, exhibited the most instances of social cues:

D3: "...he says that we're all capable of doing physics but we've just got to put our mind to it...like he'll see us as a physics person..." (Hispanic F)

D4: "Well, like I don't know if he does it on purpose but sometimes he makes mistakes like in the problems and stuff and like the whole class laughs and then it makes us feel more comfortable because like he, our own teacher is making mistakes." (Hispanic F)

D5: "He's a funny guy. I mean you'll go in there and he'll, he'll be explaining physics concepts and cracking jokes at the same time and it just, it makes you, it makes you incorporate things, at the same time feel like you're talking to more of a friend than a teacher..." (Hispanic M)

Figure 2 is an emergent theory from this work positing that positionality cues moderate the social distance between teacher, students, and content in the physics classroom which subsequently have implications for student engagement and physics identity development. For example, Dr. P exhibited the fewest cues and students in his class also reported the greatest social distance between themselves and Dr. P as well as the content.

P1: "...he's kind of like smarter than you and he can't really just like dumb it down, you know. Like I have no doubt that he's like excellent in physics but sometimes it's like over your head." (White F)

P2: "I think sometimes he could be like almost too smart for us...like his understanding of the stuff is like so great that I feel like he thinks that like we'll understand it like really easily and sometimes we don't." (White M)

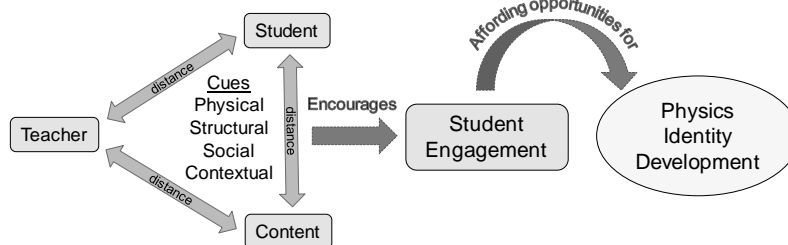


FIGURE 2. Teacher positionality, student engagement, and physics identity development.

An example of the evidence supporting the link between positionality, engagement, and physics identity development (Figure 2) can be seen in the following quote where a student discusses how the obscuring of social boundaries (teacher’s social cues) leads her to “put herself into” class (engage more), and then internalize an expectation by showing herself that she “could do it”, thus indicating an opportunity for physics identity development.

D5: “...I’ve never really been a science person but with this class like, I don’t know, I’ve really wanted to go into like, I put myself into it, I like really want to try.” [When asked why] “I believe it was the fact that he really wanted us to succeed and was willing to do anything to make that happen. He was always there after school and early in the morning if we had questions, and he had many review sessions at ---. I just didn’t want to let him down and put all of his effort to waste. It’s also that I found the material so difficult that I wanted to show myself that I could do it.” (Hisp F)

Another example of the link between engagement and physics identity development is the internalization process seen for S1: she not only maps engagement to understanding but also to relating it to the self. This work highlights behavioral cues that allow teachers to narrow the social distance between themselves and students, and thus, facilitate the development of classroom environments where students engage in learning physics while developing their physics identities in positive ways. From the previous examples, this physics identity development includes developing beliefs in their own abilities and, therefore, placing higher expectations on themselves, and finding personal relevance and interest in the material so that they can relate it to themselves.

CONCLUSIONS

Our findings suggest that teachers’ physical cues (space and hierarchical stance occupied), structural cues (dynamic nature of the classroom allowing alternating roles), contextual cues (including students’ thoughts and experiences), and social cues (obscuring

traditional boundaries between teacher and student) affect the relational structure in the classroom, which is critical to students’ extending themselves, taking risks, and engaging in the learning process. This relational structure moderates the social distance between the teacher, students, and content. A hierarchical relational structure increases the social distance perceived by students between themselves and the teacher who they often associate closely with the content, and increases the personal risk associated with engagement. Less hierarchical relational structures can liberate students by making engagement less personally threatening. Subsequent engagement with the material then opens up opportunities for being recognized, finding interests within the content, and feeling a personal sense of accomplishment when learning the material. These opportunities are particularly important since prior work shows that feelings of recognition, interest, and competence lead to physics identity development [10,12].

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