AN INFORMAL PHYSICS CLUB WITH YOUNG WOMEN LEADERSHIP: A COUNTERSPACE FOR DEVELOPING PHYSICS IDENTITY

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Research shows that by the time female students reach high school age they are much less likely than other students to see themselves as "physics people," and are less interested in pursuing physics majors or physics-related careers as they enter higher education. This lack of interest, which is often the result of societal and cultural factors, contributes to the persistent marginalization of women in physics. In addressing this historical problem, physics teachers can play a critical role in engaging young women and challenging stereotypic ways of thinking about and doing physics. In particular, by disrupting traditional cultural messaging and norms, teachers can facilitate young women's physics identity development. However, the existing culture of power in many physics classrooms, structural constraints of formal schooling, and often restricted curriculum may not provide a safe space for female students to enact physics identities in ways that are personally meaningful. Thus, we argue that counterspaces beyond existing classrooms are needed to create and sustain engagement. In this exploratory investigation, we examined the characteristics of an informal physics club initiated by a high school physics teacher and run by his female students to understand if and how this club emerged as a counterspace that promotes physics identity development for female students. This paper focuses on data from a focus group interview with five leaders of the club and the physics teacher. We show that recognizing and celebrating communal goals in this club, along with young women's leadership, were important factors in creating a counterspace for physics identity development. As such, we recommend establishing these types of informal physics learning spaces as counterspaces that can facilitate the development and expansion of physics identities among female students.

Keywords: Non-formal Learning Environments, Gender Issues, Physics

INTRODUCTION

Studies have highlighted the persistent underrepresentation of women in physics as well as the depressed opportunities for young women's physics identity construction (Hazari, Cass, & Beattie, 2015; Wang & Hazari, 2018). As a consequence, by the time female students reach high school age, they are much less likely than their male counterparts to see themselves as "physics people" (Nissen, 2019). Despite this fact, female students who choose to continue their physics education in college have been found to be strongly affected by their high school physics experiences (Hazari, Brewe, Goertzen, & Hodapp, 2017). This finding indicates that physics teachers can and do play a critical role in reversing a downward trend in attitudes towards physics. As such, a national project was launched to mobilize high school physics teachers to begin addressing deep-seated historic issues of gender bias and facilitate physics identity development, particularly for female students (Cheng et al., 2018; Potvin et al., 2022). Drawing from critical race and feminist theories, the resources provided by this project focus on presenting counternarratives that disrupt normative stereotypic narratives about who does

physics and what physics is. These classroom resources have been shown to have significant positive effects for female students' physics identity development and intentions to continue studying physics (Cheng et al., 2018). However, the existing normative nature of school science often transmits a culture of power (e.g., curricular boundaries, lack of student agency, teacher-centeredness) (Barton & Yang, 2000). Therefore, it is difficult to sustain counternarratives or disruptions to normative identities/content/practices without creating new spaces. Prior work, which mainly focused on the college-level or workplace, found that "counterspaces" were a critical solution for establishing and sustaining counternarratives (Ong, Smith, & Ko, 2018).

COUNTERSPACES, COUNTERNARRATIVES & COUNTERSTRUCTURES

Solorzano, Ceja, and Yosso (2000) defined counterspaces as spaces in which there are active or proactive attempts to prevent the reproduction of marginalizing patterns and that allow minoritized groups to engage in learning and reflect on their experiences in ways that help grow their sense of belonging and nurture their multiple identities. In the context of physics education, counterspaces can create an environment where historically marginalized groups (e.g., young women) can develop a shared physics identity beyond the normative stereotypic constructions. Ong et al. (2018) posit that counterspaces are a critical refuge from negative and marginalizing experiences in STEM, such as microaggressions and low sense of belonging, that lead minoritized groups to disengage from the discipline.

Within counterspaces, counternarratives that resist stereotypic ways of doing physics emerge and are supported. For example, physics is not perceived to be communal, either in terms of learning (e.g. working together) or what goals are valued by the field (e.g. helping others/society), but is perceived as individualistic, where demonstrating "innate ability" or individual mastery are centralized in both the learning process and what is valued (Carlone, 2004; Kessels, Rau, & Hannover, 2006; Leslie, Cimpian, Meyer, & Freeland, 2015). These normative patterns of what it means to learn physics and how that learning occurs can be disrupted within counterspaces creating new counternarratives about physics learning.

We also draw on the concept of a counterstructure, which can be conceived as a characteristic of counterspaces. It is defined as active institutionalized attempts to support marginalized groups' efforts by shifting control from brokers of power within traditional structures (e.g., white males, teachers) and centering agency and control amongst the marginalized (Lee & Harris, 2020). In traditional science classes, including physics, normative power structures typically prevail due to the constraints imposed by historic educational and curricular standards and expectations (Barton & Yang, 2000). Thus, counterspaces are often necessary to enable counterstructures of power to form and over time influence change in other spaces. Guided by these theoretical concepts, we examine the development and impact of an informal physics club for female students that was initiated by a high school physics teacher. This exploratory investigation examines how the club served as a counterspace for physics identity development and if and how counternarratives and counterstructures were supported.

METHOD

As an exploratory investigation into a physics club of predominantly Latinas (that had been independently initiated by a physics teacher and which had rapidly grown over three years), we conducted a narrative-focused group interview to begin understanding the ways in which this club may be creating a counterspace for young women of color. Previously we had informal conversation with the physics teacher and administered a pre-post survey on physics identity among club members. However, the data for this study came from a 90 minutes focus group interview. The interview was conducted with the physics teacher and five student club leaders, all-female, four in 12th grade, and one in 11th grade. All the students self-identified as Hispanic. Guided by our theoretical lenses, we used thematic analysis (Clarke & Braun, 2017) to identify features of the club that promoted physics identity development through shared multiple identities and sense of belonging among the members (counterspace), non-normative narratives with respect to physics and physics learning (counternarratives), and agential non-dominant structures (counterstructures). In the next sections, we introduce Mr. S, the physics teacher, and what inspired him to start a physics club, followed by findings of the analysis and emerging themes. Note that emphasis (bolding) in the quotes was added to illustrate central points related to the themes.

HOW THE PHYSICS CLUB STARTED

Mr. S was a teacher we had worked with as part of a larger study and contributed to the development of equitable/inclusive class resources. He has been implementing these co-created resources in his physics classes for four years (and still continues). Mr. S's background is in engineering and physics, and he has more than 35 years of experience teaching physics and other science courses (e.g., environmental science). His school is located in a large urban district with a high representation of Hispanic students (more than 90 percent). Prior to the physics club, Mr. S started an engineering club as part of the Southeastern Consortium for Minorities in Engineering (SECME). But since his participation in our larger study, he felt the need to go beyond the confinement of curriculum and class time to better engage and encourage his students, particularly young women, towards their physics learning and career pathways.

> The club is just to promote, just to do activities in the school and [...] students can see those activities. [...] I promote [physics] to everybody. **But the girls**, after the second lesson[10], **they're going to feel more attraction for [physics]** and [...] they realize they can do it. [The] lesson basically motivate many of my students to be part of the physics club. They ask me about that [...] **then I start to talk to them to participate in the club.**

[10] Mr. S refers to the Women in Physics Lesson, one of the class resources developed in our larger project. The lesson challenges narratives that relate physics to masculinity and frame physics as an individualistic pursuit of "pure" science as opposed to a culturally driven field and community and exposes the structural and cultural barriers that prevent many individuals, particularly women, from pursuing physics. Read more about it in Sabouri et al. (2022) and refer to the website for the full lesson (APS engage, 2022).

The club started with about 16 members and over three years it grew to 27, which was when we conducted the focus group interview. The club activities included participating in workshops, attending presentations by invited speakers from universities, organizing career fairs and science nights for parents and students, and participating in regional and national science competitions. These activities can be characterized as normative types of physics activities (e.g., competition or presentation). However, after analyzing the interview transcription, two themes emerged indicating how the club was a counterspace with a counterstructure promoting new ways of learning physics, hence disrupting normative narratives of physics: (1) the leadership by young women, and (2) the communal culture of the club. Next, we further explain these themes and present evidence from the interview data.

GIRLS' LEADERSHIP CREATED A COUNTERSTRUCTURE

Since the establishment of the club, Mr. S has been purposefully encouraging his female students to join the club. Moreover, he identified those with strong leadership skills and invited them to take the club's management role (e.g., president).

> I give [my female students] the chance to have the position, [...]according to the history in this school, I really like to give [them] **an opportunity** [...] **that I think they deserve**. […] (Mr. S)

In addition to nurturing their skills and potentials, by positioning the young women as leaders, Mr. S anticipated that other students would see them as a role model which would encourage them to participate in club activities and experience physics learning, although they might not necessarily feel comfortable or confident to do so.

> If we do organize a club with a very good leadership, like [these students] are, **they [become] examples, you know, as a student**. [They] are responsible and **the other students see them as leaders** [and] they see that they can [be] [...] I know if I do this, we are gonna have a lot of people here [in the club]. (Mr. S)

Mr. S's recognition was not hidden but visibly noticed and acknowledged by the members.

> Mr. S approached me and (Angela) […] he asked us both because …well, I assume **he liked our work and how we work together** [...] he asked us to be president and vice president of the [club]" (Blanca).

Prior research studies showed that teachers' recognition in ways that are meaningful for students is a strong predictor of whether they identify as a physics person, someone who can learn and do physics (Hazari et al., 2017; Wang & Hazari, 2018). Drawing on these findings, in this club, we state that Mr. S's recognition and encouragement facilitated students' physics identity development, and that motivated other students, in particular female students, to join the club.

> I remember having a friend of mine **at first, she was so confused and she didn't understand Physics**. And then [...] she entered the [club] and actually organized the stuff and everything, she was just like… This is really interesting. And it's not as complicated as I thought (Cara)

By positioning female students as club leaders, Mr. S shifted the typical power structure, often seen in STEM clubs, where male students overtake the decision-making and material manipulation (Witherspoon, Schunn, Higashi, & Baehr, 2016). Cara, who did not initially see herself as a physics person, took on a leadership role (organized) which helped her more meaningfully engage in a way that she directed for herself. We argue that designating leadership positions (at least initially) to female students and recognizing their skills created a counterstructure for this club, which led to bringing other young women into the club to engage with physics learning and take leadership in this space.

COMMUNAL GOALS & AMBASSADORSHIP PROMOTE COUNTERNARRATIVES

Two existing narratives around physics are: (1) it is an individualistic field as opposed to a collaborative and communal discipline (Bruun, Willoughby, & Smith, 2018; Kessels et al., 2006), and (2) it positions innate ability found in a dominant group, mainly white males, or exceptional cases of other groups (e.g. women) as superior and necessary for learning and succeeding in physics (Archer, Moote, Francis, DeWitt, & Yeomans, 2017; Leslie et al., 2015). These normative narratives around physics often discourage female students, unconsciously and consciously, from engaging in learning physics (Diekman, Brown, Johnston, & Clark, 2010). In contrast, in this physics club, both of these narratives were challenged and disrupted.

> [T]he people in the club […] **were really welcoming. And if you didn't know the subject they would teach you**, help you to understand more. And that sense of community also really helps me […] want to stay here and I want to help others to understand and be more interested […], to share that common… like in the subject. (Cara)

Instead of identifying certain types of talents or "ability" in physics, the club members welcomed everyone and supported each other in learning physics. The "sense of community" as opposed to competing established the club as a counterspace. Moreover, members recognized the communal culture as a vibe of the club:

> …all of us in the club have that dedication, that time management, that ability to be flexible for the club and be able to stay after school and **show a love for the club** through lab demonstrations, **through helping other classmates with physics work**. (Angela)

These young women not only saw the club as a safe space to expand their physics identity and create engaging and meaningful learning environments for themselves, but they also became motivated to inspire others to pursue and persist in learning physics.

> I had this fire to show that women can also do it, to show others who have that idea and that stigma […] women aren't really seen and they shouldn't be in it. So that would **draw me to help the club be the best** it can just to show everyone that minority such as women and Latinos can also be a major role in Science." (Angela).

Angela felt that it was important to be an ambassador for others to disrupt normative notions about women and LatinX students' place in physics. Together with the communal focus of the club, this became a way in which the club promoted counternarratives that resisted dominant narratives about who does physics and how it is done.

CONCLUSION

Several research studies have shown the effectiveness of informal science programs (e.g., afterschool or summer camp) as a way of engaging young women in science learning and developing their science identities (Adams & Gupta, 2017; Riedinger & McGinnis, 2017). However, a limited number of studies have focused on physics learning and mainly explored the impact of informal programs on college-level students (Fracchiolla, Prefontaine, & Hinko, 2020; Hazari, Dou, Sonnert, & Sadler, 2022; Prefontaine et al., 2021). In this study, we aim at addressing this gap in the literature by examining the characteristics of an informal physics club that facilitated female students' engagement in physics activities and learning, particularly in ways that might disrupt normative conceptions.

The theoretical lens of counterspaces, and within them, counterstructures and counternarratives, guided our exploratory study utilizing a focus group interview with club leaders and the founding physics teacher. We learned that designating leadership positions to young women disrupted the normative power structure and created a counterstructure for this club. Unlike formal physics/science classrooms, where male students often dominate the conversation and the flow of the activities (Wieselmann, Dare, Ring-Whalen, & Roehrig, 2020), in this club female students were responsible for decision-making and setting the norms. This counterstructure, initiated by the teacher, encouraged female students who may not have seen themselves as a physics person to engage in the club and shifted their views about physics learning. Prior work in physics has shown that certain types of leadership ("inchargeness") can actually lead to more equitable interactional outcomes such as when the student leader distributes voice to others (Jeon, Kalender, Sayre, & Holmes, 2020). Similarly, the club under the leadership of highly communal young women became a counterspace for facilitating and nurturing female students' physics identity development. Additionally, all five club members emphasized that pursuing and promoting communal goals were at the heart of the club. The establishment of a collaborative and communal culture allowed the emergence of counternarratives about physics which, as a result, was encouraging others to join the club and see themselves as physicists.

We acknowledge the limitations of this small exploratory study and do not claim the generality of these results. Furthermore, while there were non-normative constructions of physics learning in the club, many normative approaches to physics were also upheld. For example, more work is needed to better understand how normative physics content can be disrupted within informal spaces. However, theorizing how structures/experiences within this particular club facilitated the development of a counterspace is important; by leading the club's activities, these young women created a joyful, safe and meaningful learning space for themselves. As such, we recommend that counterspaces with similar counterstructures in informal STEM education might provide a critical opportunity for challenging and disrupting normative physics narratives that marginalize young women from participation and pursuit of physics.

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