Considerations for Inclusive and Equitable Design: The Case of STEP UP Counternarratives in HS Physics

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While physics is often promoted as being for everyone, its cultural narrative, i.e., what physicists do and who they are, has been and continues to be created by a dominant social group. As such, many students who come from marginalized backgrounds in physics are required to fit themselves into its narrow culture that does not reflect who they are and how they see the world. As physics educators, we have unconsciously internalized this narrow physics culture and need resources to help broaden our perceptions. To this end, we suggest some design principles for creating materials that help physics educators reflect on these issues and disrupt inequitable structures in their classrooms. We draw on the STEP UP project to exemplify how these design principles were implemented.[1]

Design principle I: Inclusive development through co-creation

As educators, we are continually designing, reworking, and implementing materials in our classrooms to make learning more relevant and meaningful for students. An important approach in this process is co-creation with others (students, community members, and other educators); including broad perspectives in designing materials allows them to be more equitable and have a broader impact and relevance.[2–5] The resulting materials co-created with students help draw on their funds of knowledge, support cultural relevance for students, and promote their science identity development.[2,4] Incorporating aspects that are relevant to students' identities, knowledge, and cultures is a crucial aspect of effective co-creation. When educators design materials together, they expand their teaching strategies and practices.[5] Furthermore, teacher–researcher partnerships and co-creation break down barriers between research and practice where research can translate into practical solutions[6] and practice refines research theories. As such, the co-created materials, especially those designed with minoritized groups, tend to be more equitable and accessible for students.

In the STEP UP project, a team of high school physics teachers,[7] researchers,[8] educational professionals,[9] and students[10] came together and co-created the lessons and materials. The teachers taught across the U.S., including inner-city urban, suburban, and rural schools. Both the teachers and their students identified with diverse backgrounds in terms of gender, race, ethnicity, immigrant status, and backgrounds in physics. The researchers, who also come from diverse backgrounds, had expertise in gender and equity issues in physics and science more broadly. Finally, students, including young women from minoritized racial/ethnic groups, provided guidance on the content of the materials (e.g., career profiles, discussion prompts, and connecting to their interests). This team effort led to two core lessons (a Careers in Physics lesson and a Women in Physics lesson) and an Everyday Actions Guide for supporting inclusive classroom culture (described after the design process sections).

Although having a large and diverse team allowed us to incorporate more varied perspectives in co-creating, it is not always possible to gather such teams (e.g., due to limited resources and time). However, co-creation can be done on smaller scales. For example, teachers can co-create materials with their students, members of the local community, colleagues at their schools, or colleagues attending local and regional conferences. Students' ideas and feedback can be incorporated through various approaches (e.g., cogenerative dialogues[5]). Online platforms and virtual communication tools can also allow collaboration to go beyond the scope of schools.

Design principle II: Drawing on prior insight

Another important aspect to consider in the design process is prior theoretical and research insights. While theory guides the goals for designing materials, prior research evidence shapes the design to have a greater impact. For example, in equity work, one might focus on theories related to cultural relevance, intersectionality, universal design for learning, or a combination of theoretical insights to guide the goals and designs of lessons.[11–14] Reviewing prior studies leveraging these theories provides insight into what has previously been effective and reveals previously developed materials that focus on different aspects of equity.[15] While drawing on prior insights is important for initial design, this process also includes feedback,[11] which will be described further in the next section.

In developing the STEP UP materials, our main goal was to engage and inspire young women in their physics learning and future physics pursuits. Therefore, we drew upon the literature on the experiences of women in physics, science, and STEM classes more broadly. A cornerstone of the work that we looked at was how students, particularly female students, develop physics identities.[16–19] This involves theories and studies examining how physics identities are shaped by culture and how stereotypes, societal gender roles, and implicit/explicit bias feed into dominant cultural narratives about physics.[20–22] The STEP UP materials were designed to promote physics identity development by creating classroom environments that acknowledge, leverage, and reinforce students' capabilities, provide many opportunities to be recognized, connect with students' interests and values, and promote communal and supportive learning environments.

We drew from prior research on strategies that have dis-

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rupted dominant cultural narratives that exclude diverse perspectives[19,23,24]; in particular, the concept of "counternarratives" guided our design. Counternarratives are alternative or opposing examples that offer "new windows into the reality of those on the margins allowing new and different possibilities to be showcased, and by combining elements of the story and the current reality, thus constructing another world that is richer than either story or reality alone."[25] Counternarratives can disrupt narrow and normative storylines that marginalize the perspectives of women, members of minoritized racial/ethnic groups, individuals with disabilities, and other oppressed groups, as well as the intersections of these identities.[23,26] The STEP UP materials embed counternarratives that disrupt the historic cultural storyline of physics, which lacks diversity and the contributions that come with diverse perspectives.[27,28] We will further explain how counternarratives were used in the lessons after describing the final design approach.

Design principle III: Feedback/evidence of impact

While co-creation and drawing on prior insights are important for designing equitable materials, evidence of impact is important for ensuring that the materials are supporting students from minoritized groups. Pursuing evidence of impact also enables opportunities for students to provide feedback and for educators to critically reflect on their lessons/activities to be more culturally and intersectionality conscious.[11] Without this feedback/evidence there is a danger of relying on idiosyncratic response (e.g., a single person's response to the materials) or less methodical feedback (e.g., how a teacher "feels" a lesson went), which could be biased toward a dominant group who are more empowered to voice themselves. Thus, collecting evidence and feedback, particularly from the most disempowered within physics classes, is important. Furthermore, use of evidence to refine materials has been found to improve both teacher and student outcomes.[29]

In STEP UP, we examined the impact of the lessons and materials on students' physics identity development, particularly young women and minoritized racial/ethnic groups by conducting pre–post surveys longitudinally.[30,31] The results of two studies showed a significant positive impact on students' physics identities, in particular, for their future physics intentions.[30,31] Our findings indicate that the positive impacts were larger for females than non-female students. Additionally, there were significant gains in future physics intentions for students from minoritized racial/ethnic groups in physics. The results contrast with other research showing that there is often a drop in attitudes toward physics through a semester of studying introductory physics.[32]

Having the advantage of a team working together, we were able to collect evidence on a larger scale, across multiple schools and states. However, individual teachers can also collect and use similar data on a smaller scale as feedback for their practice (and there are resources to help[33,34]).

Description of STEP UP materials and embedded counternarratives

Careers in Physics lesson (counternarratives about what physicists do)

One of the goals of the Careers in Physics (CiP) lesson was to challenge two particular narratives related to physics: (1) physics is individualistic and not communal, and (2) people in physics come from an exclusive group who pursue a narrow set of careers. To achieve this goal in designing the lesson, the STEP UP team collected and examined a large set of profiles of individuals with degrees in physics and selected those that met the following criteria: (1) they have diverse identities (e.g., women and people of color), (2) their career interests are in areas that are culturally and historically less associated with physics or with masculinity (e.g., life science-related or climate/environmental careers), and (3) they pursue communal goals (e.g., helping others/society or working with others) in their career. During the lesson, students are matched with these profiles based on their interests and goals, then discuss them with the class. This discussion allows them to challenge the dominant narratives about who becomes a physicist and what they do as well as provides counternarratives to transform and expand that storyline. It is crucial that students can envision themselves in these expanded narratives as members of the physics community. To scaffold this process, students are guided to create their own career profile as a physicist incorporating their personal interests and goals.

The CiP lesson can be implemented anytime of the year; however, implementation is recommended at the beginning of the year to help students get to know each other and create a classroom community while also connecting to physics. The lesson opens up conversations about how physics is instrumental in various career paths and encourages students to seek connections between physics and their interests, particularly what they hope to do in the future. If displayed in the classroom, the student-created profiles can be a powerful visual reminder of how physics can relate to their goals while recognizing who they are and want to be. The CiP lesson is divided into sections that can be implemented on different days to accommodate curricular scheduling and the needs of individual classrooms.

Women in Physics lesson (counternarratives about becoming a physicist)

The Women in Physics (WiP) 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. In particular, it aims to expose the structural and cultural barriers that prevent many individuals, particularly women, from pursuing physics. The lesson disrupts the narrative that innate ability found in exceptional groups,[22] mainly white males, is necessary to learn and succeed in physics. The WiP lesson is designed in a way that the counternarratives mainly emerge as the product of students' active participation in and contribution to a whole-class guided discussion. To situate the problem and provide initial counternarratives, students examine the statistical data of women physics degree holders in non-U.S. countries where the percentages are much higher than those in the U.S. (as high as 60% compared to ~20% in the U.S.). Then, they examine research around the societal and cultural norms in several of these countries, highlighting ways in which women face fewer structural and cultural barriers. Opening the lesson with this evidence aims at (1) disrupting the beliefs that attribute participation in physics to masculine identities and (2) motivating students to reflect on societal/cultural norms and existing structures in their own context. Facilitated by the teacher, students are encouraged to examine how each of these social and cultural norms and structures in education has (1) impacted their beliefs about their ability and/or interests in physics-related careers and (2) created obstacles or barriers for them to pursue such goals. This discussion-based lesson allows students to notice existing narratives and develop new counternarratives while analyzing data and constructing arguments.

It is recommended that the WiP lesson be implemented after establishing a familiar and ideally safe classroom atmosphere so that students can engage in the discussion openly. The lesson includes participation guidelines for the discussion,[35] and it is highly recommended for teachers to review them with students beforehand (and ideally throughout the year) to establish appropriate conduct during discussions. The lesson can also be implemented to honor important events for women such as Women's History Month or International Day of Women and Girls in Science. Furthermore, like the CiP lesson, the WiP lesson is divided into multiple sections that can be implemented on different days to accommodate various teaching and learning contexts.

Everyday Actions Guide (counternarrative emphasizing culture)

For many students, teachers are often their only source of encouragement and support in physics. Thus, how teachers act, what they say and do not say, and the classroom environment they foster has a profound impact on students' sense of recognition as a physics person.[18,36] The Everyday Actions Guide (EAG) provides teachers with tools to examine their practice and reframe their actions in ways that disrupt the dominant culture in physics and promote physics identity development among minoritized groups, particularly young women. It is divided into five sections that suggest actions during (1) individual interactions with students, (2) whole-class discussions, (3) group work, (4) assessment/planning, and (5) out-of-class interactions. The EAG includes suggestions that facilitate recognition of students, particularly those who teachers often overlook as not being "physics people." For example, it suggests that teachers share female students' success with their families, provide academic opportunities in physics, and value many different skill sets. A set of suggested actions are also presented in the EAG to promote a growth mindset,[37] in particular (1) emphasizing the learning process as opposed to its end product, (2) encouraging and celebrating collaboration rather than competition, and (3) normalizing struggle as part of the learning process instead of punishing it. These suggestions help create and nurture a communal learning environment where members of the classroom are encouraged to assist and support each other. A summary checklist is provided with the EAG as a quick tool for teachers to use to reflect on their daily practice.

Conclusions: Teachers as drivers of change

The physics community and culture has historically been driven by people with power within those structures, typically one dominant group. Teachers have tremendous power to influence who participates in this community and how they represent physics. As such, we see teachers and the students they inspire as potential drivers for culture change in physics. The STEP UP materials and community provide tools for teachers to help change the conversation by disrupting dominant narratives of who does physics and what physics/physicists can and are doing in the world.

Even though studies show that some steps toward changing the narratives around physics are being taken,[38,39] the work is far from being done. While the STEP UP materials were primarily focused on female students, there is a need to continue to design, test, and implement materials that extend and address intersectionality with respect to minoritized race/ethnicities, disabilities, language, class, LGBT+, generational status, immigrant experience, non-Western perspectives, religion, and many other identities that have been and are currently marginalized from contributing to defining physics and participating in physics communities.

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