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Invited, Valued and Welcome? Negotiating Diversity and Equity in Physics

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For several years now, women and minorities have got encouraged to choose physics programs and to enter physics faculties. Nevertheless, physics and in particular high energy physics, is a field of research strongly associated with cleverness and masculinity. Barely less elitist is the image of physics and physicists in general, be it in public (e.g. parents) and media (e.g. 'Big Bang Theory') or be it at school and university. Especially newcomers struggle with this imaginary gate keeper. Next to talent and diligence, physics students need a great deal of confidence and believe in their abilities as future physicists. It is therefore not enough to invite women and minorities to enter physics programs. Instead, we must understand the gendered, classed, and raced image of physics in its policy of knowledge-producing processes. And we need to overcome the reproduction of the 'hidden curriculum' while teaching physics. Therefore, we have to reflect on the power of norms and exclusions in the culture, representation, and teaching of physics. The aim should be to make diverse people feel more valued and welcome in physics.

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1. Theoretical Background: Diversity

When we teach natural science to future scientists and engineers, we are teaching more than facts, methods, and concepts of science. We teach the 'hidden curriculum' [1]. When teaching physics, we convey for example representations and norms of physical talent, technological competence, heroes in the history of physics, presumption of white supremacy, heteronormativity, and hegemonic masculinity. In doing so, we encourage some (e.g. male, white, middle class) students and fail to support others (e.g. female, queer, of colour, working class) [2]. We therefore unconsciously reinforce existing social inequalities and prejudices about scientific literacy, promote uniformity and prevent diversity in science and technology.

Speaking of diversity among people, we should not stick to a static or essentialistic understanding of diversity. We should keep in mind that the categories of diversity such as age, gender identity, race and ethnicity, dis/abilities, religion and world-view, sexual orientation, or social background [3] are sociocultural structures to classify people, to create and support power structures among them. Instead of accepting essential differences which 'are just there', we need to keep in mind that we 'are made different' by these diversity categories to create and legitimate inequality.

Diversity studies provide a theoretical framework for reflecting on the reproduction of social inequalities and can be employed as a tool to analyse the gendered, classed, and raced policy of knowledge-producing processes. They can help in science education explore and enact material-discursive change and teach physics in a way that is welcoming to diversity and plurality in science and engineering. Diversity as a theoretical background overcomes outdated cultural norms and conceptions.

2. Empirical Findings: Gendered and raced politics in physics

Conversely to being viewed as objective and gender-neutral, physics heavily depends on societal, hetero-normative norms, and knowledge of physics is constructed within particular academic cultures by gendered people with idiosyncratic backgrounds. Consequently, the physicists' conceptions of gender relations in society are unconsciously included in the knowledge they produce. Researchers have studied the conditions physicists encounter in their daily lives as well as in science, industry and education systems. They also examined physicists' fascination of doing physics and the discriminatory structures which impact female and under-represented students and academics. In order to answer the question of how to change academic and technical fields to attract a more diverse group of people, we need a deeper understanding of the cultures in the academic fields of science and technology [4].

A look at history and statistics shows that, apart from a few Asians such as Satyendra Nath Bose or Hideki Yukawa [5], physicists are predominantly white, straight, middle-class male researchers whose contributions have been recognized in the annals of history, despite the image of physics as objective and universal. For example, material bodies, their physical characteristics, and associated natural laws have been named almost exclusively after white male actors. These historical accounts on one hand reflect that women, working-class minorities, queer people and people of colour hardly had access to physics education for centuries—a tradition that left its mark until today [6, 7]. On the other hand, these accounts

ignore the work of women and minorities in the field who have made important contributions to physics [8, 9].

Over the last decade or so, the analysis of physics' culture has increasingly become the centre of attention. Researchers focus on the styles of interactions between physicists, mechanisms of recognition and assessment cultures in physics as well as the way knowledge is being generated. They study communications in research labs, educational settings at universities, physicists' behavior at conferences, and contents of physics textbooks [2, 10, 11]. Moreover, by wittingly or unwittingly making statements about gender, gender differences and gender norms, knowledge generated in natural science and technology actually includes socio-culturally established gender relations. For example, in the days of industrialisation and steam engines terms such as work, power and energy entered thermodynamics theory together with the idealistic concept of industrialized masculine bodies pertaining to an exclusively male profession [12].

3. Practical Experience: Negotiating equity and diversity in physics

These empirical findings were an eye-opener to my physics teaching of classical mechanics to first-year students in engineering programs at a University of Applied Science in Germany. Sensitized for the gendered and raced policy in physics, I developed strategies to value and welcome diversity and equity in my physics courses. Evaluations and personal feedback from my students showed that especially women and minorities found this innovative way of teaching motivating and encouraging. Some students explained it was this experience that helped them to finally complete their studies with success [13]. In the following I will give some examples how this theoretical background and the empirical findings helped me analyse the situation in the lecture theatre and create inclusive space for new thoughts and social justice. These approaches may as well be transferable to courses in physics major classes or physics lessons at school.

3.1 Challenging the narratives of physics

Where appropriate in my course of classical mechanics, information about the contexts in which physics knowledge developed is included. The aim here is to show that people from different professional fields such as medical doctors, beer brewers, clerics etc. have successfully concerned themselves with physics. Beside the fact that physics learners are expected to understand laws and explanations almost instantly, observed physical phenomena could very often only become established knowledge after long-lasting negotiation processes. In my teaching of classical mechanics, I use examples of earlier physicists who had originally either worked in a different academic field (e.g. physician) or had no academic degree at all (e.g. craftsman) to foster my students' confidence and to stimulate their participation. Whenever possible, I present female physicists and female academics working in the field such as the French noblewoman Èmilie du Châtelet, who translated Newton's work and made it known in France. To include role models for my black students and students of colour, I choose some short explanatory videos, where black lecturers and physicists of colour demonstrate and explain phenomena with equipment we do not have in the collection at our university.

Physics is (re)presented via written texts and oral narratives. This opens up a possibility to intervene during the physics lecture. The maths problems offer a good chance of challenging

traditional perceptions of gender. German textbooks quite often use weapons, sportsmen and male physicists to explain physics. Therefore, one can challenge gender roles by choosing an allegedly "atypical" sport for the tasks. For instance, in one of my tasks on calculating the conservation of angular momentum I replace the usual female ice skater with the male Russian, three-time world champion figure skater Evgeni Plushenko and let my students watch his quadruple and triple jumps and excellent pirouettes. Many of the male mechanical engineering students feel visibly disturbed by Plushenko's female masculinity and start giggling.

In a task on kinematics developed by one of my colleagues, a lion is chasing after an antelope for a short time and the students are asked to calculate if the antelope will escape or be caught by its hunter. I use this particular example to explain to my students the thinking patterns of physics. I present the task "Lion hunts antelope" and then show the short film "Lionesses chasing a zebra". The idea here is to enable the students to see that natural movement patterns such as acceleration and braking, change of direction as well as the necessary teamwork are being left out and end up as rectilinear and regular movements in the task. Moreover, the students see that lionesses hunt as a team whilst lions do not at all. In this way, the students can question the still prevailing gender ideas of active masculinity and passive femininity that date back to 19th century.

3.2. Enacting Material-Discursive Change

Physics is performed through experiments in the lecture theatre. Interdisciplinary gender and diversity research in general and also educational research study physical objects and their meaning for knowledge production and teaching. To physically experience the conservation of the angular momentum, a person sits on a rotating stool chair and is being turned round while holding a heavy dumbbell in each hand. With both arms stretched out in a horizontal line, the moment of inertia grows and the angular acceleration of the rotation slows down. Keeping the weights close to the body, the mass moment of inertia decreases and the angular acceleration increases. We can observe this effect with figure skating pirouettes or the somersaults performed by gymnasts and high divers.

Instead of the usual call for a "strong male student", I invited all students to participate in the demonstration. One female student took part on the condition that she had to hold only one dumbbell in her hands. We observed that the intended effect would also show with only one weight held in both hands. Consequently, I will carry out this experiment in the future with only one dumbbell. In this way, all students have a fair chance to participate in the experiment: those who would otherwise feel embarrassed when asking for a "lighter" variant of the experiment in front of the whole group as well as those who would refrain from taking part, believing they lacked the necessary physical strength. Such a change in the material-discursive choreography of student, teacher, dumbbell, rotating stool, and audience could turn the usually externally oriented demonstration of masculine strength into an internally oriented bodily experience of the rather difficult to grasp concept of angular momentum.

4. Conclusion

Although gender, class, and race as well as other categories of social inequality might not be visible in physics at first sight, masculinity, whiteness, and heteronormativity [6] are hidden messages in the teaching and presentation of physics in the lecture theatre and beyond. My

explorative ventures into physics education revealed academic teaching methods that may well help challenge the culture of physics, question its white, heterosexual, and masculine connotations, and enact material-discursive change.

Being encouraged by the theoretical framework and empirical findings of gender and diversity studies, we will successfully challenge physics textbooks and educational settings at universities and make communications in research labs, physicists' behaviour at conferences and the image of physics in the greater public more welcoming and appreciative to a substantially greater diversity of future physicists.

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