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Comprehensive and practical method for integration of Equality, Diversity and Inclusion (EDI) into engineering education

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***Abstract*— In this paper, a new approach to work with the underrepresentation of women in engineering is presented: instead of looking at ways to make the education more attractive to women, queering the engineering education is suggested. The education intervention presented problematizes the traditional professional engineering role and the effects it has on society. A metaphor is introduced to support the transformation: theatre. In the theatre metaphor, the frontstage relates to the outcomes of the future work of the engineers we educate (i.e. innovations, technologies, cities, etc.), the backstage is where our students will perform their future work (i.e. the future workplaces), and behind-the-scenes is where they are trained to become engineers (i.e. the education). Teaching modules for both teachers and students are presented, together with tools that can be used in learning the gendered aspects of the specific subject matter at hand.**

***Index Terms*— diversity, engineering education, feminist, gender, queer**

I. Introduction

Many years of work and effort to increase the diversity among students in engineering fields have yielded very little change: in many engineering streams, women students are still low in numbers [24], [37]. In this paper, a new approach to work with the underrepresentation of women is presented: instead of looking at ways to make the education more attractive to women, an attempt to start queering [4] engineering education is made. The intervention for integration of equality, diversity and inclusion (EDI) into the education presented here problematizes the various ways that traditional professional engineering roles and values are perpetuated, and the effects they have in society. The method asks engineering teachers to look at the education as an instance where agents creating the innovations, cities, technologies and so forth. of the future are produced. It proposes that teachers assess their own course content and education practices and incorporate a higher reflexivity relating to the consequences of the subject matter in terms of equality and inclusion. The method also helps both students and teachers to break free from the taken-for-granted views of technology and fosters a deeper understanding of its role in society. Queering engineering education can help us to break the strong connection between masculinity and the STEM fields [13], [16], [27], [28], [51], that hinders women and non-masculine people from visualizing and aspiring for a career in engineering. In other words: queering helps to reimagine and reinvent the engineering profession.

The educational intervention presented here is comprehensive in the meaning that it covers EDI in various aspects of the education (with the help of the metaphor of a theatre), and it is practical because it is described in a practical way. Focusing on the practical aspect of the intervention is prioritized because the shift of engineering education is urgent. The intervention described relates to a method described by Bianchini et al. from 2002 [5], where feminist and social studies of technology were taught to engineering and natural science teachers. With that method, it was found that dissenting perspectives were not always productive: conversations were not always able to help teachers reach a deeper understanding, and the divide between social and natural sciences was further sedimented. In the current method, the aim is to bring the research on science and technology from social sciences (such as Science and Technology Studies and the gender and technology research field) closer to an engineering perspective and understanding of technology and have a less social-sciences-heavy approach. The current method also differs from the method presented by Bianchini et al. [5] because it provides teachers with tools they can use in their teaching, and because teachers are asked to make changes to their own courses, which are then discussed among a community of teachers. This makes the current approach more hands-on and practical.

When we talk about EDI in STEM education, we often refer to form of equality, diversity and inclusion in the classroom or learning situation. We are concerned with evaluation methods and different learning styles, teamwork and lab work, and making sure that assessment methods are just. Focus on form, while important, leaves out the EDI aspects related to the *content* of engineering education. In order to facilitate talking about the content and differentiate it from the form, I use the metaphor of the theatre (inspired by [21]).

In what follows, first the theatre metaphor is presented, and then the training session for teachers in presented, followed by the teaching tools provided for using with students. Then some

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issues within the theatre metaphor are addressed, and finally a few concluding remarks are made.

II. Education as theatre

The theatre metaphor brings in a perspective of education that has three different spaces or dimensions: frontstage, backstage and behind-the-scenes.

A. Fronstage

The frontstage refers to our students' future work outcomes. We teach students to perform innovation/technology/ products/etc. in their future roles as professionals. In the metaphor, we train them to perform on the frontstage in the future, where we acknowledge and are aware of the effect their future work efforts have on society (represented by the audience in the theatre). EDI on the frontstage relates to creating artefacts in the future that include EDI-perspectives, i.e. algorithms that are not racist nor sexists, telephones that can be operated with the same facility with small hands as large hands, cars that are just as safe for male-type bodies as female-type bodies, and self-driving cars that can recognize people with a variety of skin colors. In short; this is about *producing equitable technology/ innovation/cities and so forth.*

B. Backstage

Behind the frontstage is the backstage: the place where all the work happens that make the performance on the frontstage possible. In the metaphor, this are the future workplaces where our students will work. EDI content here relates to *equitable production of technology/innovation/cities and so forth.* Here we find the diversity of future workplaces.

C. Behind-the-scenes

In the theatre metaphor, EDI in the education setting, for example inclusion in the classroom and fair assessments, is placed behind-the-scenes. The reason for this is that behind-the-scenes we are rehearsing and preparing students to become engineers. One big difference between the stage and behind-the-scenes is that what happens on the stage can be evaluated in the students works: behind-the-scenes is all about how we set up the learning situation and as such, if anything is examined here it is the teachers, not the students. The distinction between behind-the-scenes, front- and backstage is an analytical move that helps teachers to look at different aspects of their teaching and makes it easier to understand how and when to include EDI in education.

III. Teaching teachers – a learning situation for teachers

The theatre metaphor is used in a training session consisting of three steps, presented in Table I. In step one, teachers get together for a workshop focusing on opening up their eyes to the EDI aspects relating to the front- and backstages in their field. In this workshop they are presented with the inequalities and bias in current technologies (frontstage) relating to their fields. Examples include gendered transport patterns[1] (talking about the gender aspects of a bridge), biased AI systems[2] (talking about racist soap dispensers, facial recognition systems and self-guiding vehicles), potty parity[3] (talking about how both sex and gender factors make the need for toilets bigger for women), traffic safety[4] (talking about the fact that crash test dummies are just scaled down versions of male dummies and only required in the passenger seat in tests), safety and legitimacy in public space[5], how we can build homes that protect the inhabitants from domestic violence[6]. In short, they are presented with feminist critiques in their own field in order to incorporate studies from gender and technology in their respective courses. So when teaching about traffic safety, they will also talk about the discriminatory current practices, and when teaching about AI, they will also talk about the sexist and racist algorithms and what needs to be done in order to not perpetuate and accentuate the bias of humans, and so forth for a wide range of topics.

Regarding backstage (i.e. what happens in organizations) they get to know about pay gaps, lateral and vertical segregation[7], unequal competence evaluations[8] and office housework[9]. When it comes to behind-the-scenes, what is covered here is queer pedagogy [32], gender-inclusive language, as well as making sure that stereotypical gender roles are not reproduced in the education [54], and to avoid actions that can cause stereotype threat [37], [46]. All examples are provided in the learning platform of the university (Canvas), together with suggestions for guest speakers.

The second step of the teacher education is applied: teachers are asked to make changes to their courses in the three dimensions; frontstage, backstage, and behind-the-scenes. They are also asked to find relevant gender and equality aspects relating to their own field in an exercise where they are provided with a set of search terms they can use with the content of their course (e.g. feminist, gender, norms, stereotypes, queer). The intention is that they find more relevant examples for their own course content. To help their work, they are provided with some example goals and objectives relating to EDI that can be incorporated into the curriculum. This is especially helpful for teachers who are accustomed to working with a constructive alignment method. They can work with 3 different modes: *introducing* the topic which means only to mention it in the course, *teach* the topic which means that it will be examined, and *use* the topic which means it will be examined in the examination of a different learning goal. All these levels are relevant and important to have in a program. To further support their work, they are provided a set of exercises and resources that they can incorporate in their courses (see more below under *Teaching students*).

In the third step, teachers are asked to present their changes to each other in a second workshop where the different

[1] Eg. [49] and [53].
[2] Eg. [9], [11], [17], [35], [47], [44], and [55].
[3] Eg. [3], [38], [40], and [42].
[4] Eg. [7], [36], and [39].
[5] Eg. [34] and [50].
[6] Eg. [48].
[7] Eg. [2] and [45].
[8] Eg. [8], [10], [19], and [31].
[9] Eg. [23].

solutions are discussed. This way they get feedback from each other and can inspire one another, and more importantly: lay the foundation for a community of practice where pedagogical issues can be discussed and developed [15], [52].

TABLE I
The three steps of the teacher training

Step 1: workshop	Introducing examples relating to frontstage, backstage and behind-the-scenes regarding EDI
Step 2: exercise	Make changes to their own course
Step 3: workshop	Discussion and feedback regarding teachers' solutions

IV. Teaching students – educational tools for the frontstage and the backstage

To support teaching EDI content on the front- and backstages, teachers are provided resources that include practice exercises and examination exercises.

A. Frontstage

Regarding frontstage content, three example exercises focus on various methods relating to *norm-critical design methods*. One focuses on deconstruction of design aspects to understand what values different design features carry and signal to users, while two others relate to personas and stereotypes that are inbuilt into products or services. Another exercise is based on the Stanford *Gendered Innovation* webpage with several gendered engineering and science research projects. Students are asked to analyze the projects (selected by the teacher or by students) and apply learnings from those projects to an artefact or phenomenon in the specific course (which the teacher may define). There is also one exercise about *Wikipedia*, which teachers can use as an examination method. In this exercise students are asked to diversify an entry of their own choice on Wikipedia that relates to the topic of the course. This could be highlighting gender aspects into a technological concept, or it could relate to the biographic descriptions of women inventors or scientists which to date is not only less developed than male inventors, but also often uses a discriminatory language [18], [20], [41].

Yet another resource teachers can use (and pick elements from) is a whole module on how to *gender-sensitize an engineering project*. This resource is built up of videos and exercises covering various dimensions of a student project ranging from target groups (and who is left out) to how sex and gender factors easily can be entangled. In this module students get to know that some of our science, which we believe to be objective and value neutral, has been guided by stereotypes and is biased[10]. This is to show students that it is easy to be biased, and then tools to help students to not be biased are provided[11]. Throughout this module, students are presented with a series of questions to pose in relation to the content of their project (no questions relate to the working process or inclusion within their own project team, i.e., the focus is solely on the frontstage).

B. Backstage

Exercises relating to backstage are about gender roles and how stereotypes are enacted in organizations today and helping students to realize that we all have a role to play in enacting stereotypes. The first education package for backstage is the *Stereotype package*. It consists of a series of online resources and an evaluation. In the first step, students watch online lectures about stereotypes in organizational contexts. In the videos, what stereotypes are is explained using Kahneman's model [26] and where stereotypes come from is addressed. Issues such as pay gap, vertical and horizontal segregation, office housework, and biased evaluation processes/the myth of meritocracy are presented. Finally, students are presented with ideas on how to challenge stereotypes, and break down the essentialist view of the difference between men and women (that many people still believe in), and include people that do not match the gender binary, and people that go against the binary stereotypes. Here, biological differences are explained in terms of stereotypes, in order to open up a possible field of action. The videos are supplemented with various online resources talking about the same issues in order to provide a variety of voices and approaches.

In the second step, the learning from the online resources is assessed. Here students are given a series of questions they need to answer in a seminar and/or a written reflection (in group or individually) where they get to assess their own ability to break stereotypes and contribute to unlock the binary system that keeps people of all genders in an iron cage. Here teachers are encouraged to add one or two papers from a list of publications[12] that describe stereotypes in engineering/STEM context and the co-creation of gender and technology. Also, two exercises are provided to help students to be more reflexive about the stereotypes they themselves embody. Rather than focusing on whether or not students are acting out biases (through exercises such as implicit bias tests), these exercises take on their personal position in a less threatening way: they get to look at themselves and which groups they themselves belong to. From this position, they are asked to think about measures they may take to change the status-quo which encourages transformative learning [6].

The above-described package is especially relevant in courses that struggle with low diversity and where teachers want to problematize the connection between masculinity and technology/science/mathematics/etc. Another teaching package is provided, the *Competence evaluation package*, which does not start with stereotypes; instead, it starts with looking at organizational practices where people are evaluated: hiring and promotion processes. This package may be more relevant in leadership and organization courses or where teachers want to focus on power relations and homosocial reproduction. The first

[10] Ex. human fertilization [30], butterflies [33], evolution [1], [22], [43] and neuroscience [14], [25].

[11] Eg. [12].

[12] Eg. [16], [27]-[29], [51], and [54].

step is a learning game; students are asked to staff a fictious organization where they are the managers. Students are provided with different applicants and need to decide who to hire to which position. This exercise can be called many different names, such as "strategy exercise", "decision making exercise" or "organizing the company" – there is no need to call it a diversity exercise since it may reveal the learning aspects of the exercise too soon. Once the organization is staffed, the students move on to the next step: analyze the organization they have created. To start the analysis, the teacher may use a pre-recorded online lecture about the consequences of stereotypes in organizational contexts (the same online lecture as in the first step of the stereotype package covering pay gap, vertical and horizontal segregation, office housework, and biased evaluation processes). In the evaluation step, they are asked to reflect (in group or individually, in written or in a classroom discussion) about their learnings with questions such as *Who was valued as competent and who was evaluated as less competent? Why?* A few shorter exercises about competence evaluations are provided as an alternative to this one, because it requires at least half a day.

All the tools and exercises are listed in Table II and are provided within the university teaching platform (Canvas) in order to facilitate import into other courses.

TABLE II
Teaching tools to work with EDI topics on the front- and backstages

Frontstage teaching tools	• Norm-critical design methods (3 exercises) • Gendered Innovation (exercise) • Wikipedia (exercise) • Gender-sensitize your project (module: videos, exercises and questions to pose in relation to your project)
Backstage teaching tools	• Stereotype package (module: videos and exercises) • Competence evaluation package (game, video and exercise)

V. How to work with front- and backstage

EDI aspects are often perceived as more difficult to work with in more theoretical or technological courses, such as mathematics or mechatronics. These are courses where the end users are far away or human end users are few. I suggest that in these courses we focus on working with backstage, with topics such as stereotypes and competence and co-construction of gender and technology (exercises described in *Teaching students*). In courses that are closer to end users, such as product development, data structures, transport systems, programming etc. we focus more on EDI aspects of the front stage such as fair algorithms, representation in machine learning, just traffic planning and traffic safety, and access to public space (examples provided in the frontstage described in *Teaching teachers*).

VI. Overlap between frontstage, backstage and behind-the-scenes

There are overlaps between the three spheres. Within the boundary between front- and backstage, some teachers may perceive that backstage is frontstage, especially where leadership and management issues are the main topics, such as industrial organization and leadership/management courses. Even when the main content of a course relates to leadership issues, the concept of backstage can still be used: leadership and organization will happen in a context where something else is being created or delivered to an end user (frontstage).

There is another way that the frontstage and backstage seem to be connected: many students and teachers assume equity on the frontstage (i.e. more just and inclusive innovation and technology) will be produced once we have diversity in the backstage (and behind-the-scenes, i.e. among students). It seems to be a reasonable assumption that products delivered on the frontstage will be equitable if they are produced in an equitable workplace (i.e. backstage); if the group of engineers developing a certain product are more diverse they will be able to understand a wider range of perspectives and use cases. However, we must teach students that there are other ways to reach more equitable products on the frontstage: all engineers must take measures and avoid the I-methodology (using yourself as the role-model for the end user) and make sure that their innovations do not discriminate. This is especially important since universities in Sweden, and all over the Westernized countries, have struggled for a long time to increase the diversity among students, especially relating to gender, without success. Since starting with increasing the numbers of women does not work, attempting to instead change the culture and course content can be a better way to increase diversity among students and reach gender parity. By working with EDI in the front stage and the backstage separately, and make sure that teachers in different engineering fields know about gender and equality aspects of their particular topics, we can contribute to creating a different engineering environment today and tomorrow, where a wider range of people can they belong. The educational intervention proposed here helps us to address the lack of diversity in a new way: through first changing the gendered and discriminatory aspects of technology and not by trying to first increase the diversity in the profession.

There is also an overlap between backstage and behind-the-scenes. Both these relate to the culture in which engineering is produced; backstage is the future workplaces and behind-the-scenes is the current workplace of our students: the learning environment. We may also teach people about future workplaces through the things we do in the education setting, and some may even claim that we must practice what we teach ourselves. Therefor the behind-the-scenes dimension goes beyond the desire to make education equitable for all. Behind-the-scenes is also a way we lead the way to practices for the

future workplaces (i.e. backstage).

VII. Final remarks

This set-up has been developed and is currently being used at Chalmers in order to mainstream EDI into the engineering education. Teachers so far have found the theatre metaphor useful in order to understand what EDI means in their education, and in order to look at their courses with the different sections in focus: frontstage (the future performance of professional engineers), backstage (the workplaces of future engineers) and behind-the-scenes (the engineering education).

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